Project # 3 (95-003)
Surveillance Requirements/Technology

FINAL PROJECT REPORT

NOTE TO READER:

THIS IS A LARGE DOCUMENT

Due to its large size, this document has been segmented into multiple files. All files separate from this main document file are accessible from links (blue type) in the table of contents or the body of the document.

I-95 CC3-95-06

Project # 3 (95-003)

Surveillance Requirements/Technology

FINAL PROJECT REPORT

Prepared by:

Loral AeroSys
IBI Group
Jackson & lull
Edwards and Kelcey

I-95 Corridor Coalition

June 23, 1995

NOTICE

TECHNICAL REVIEW COMMITTEE #3 MEMBERS
SURVEILLANCE REQUIREMENTS/TECHNOLOGY

NAME	TITLE AND ORGANIZATION
Charles Hall	TRC #3 Chair Assistant State Traffic Engineer Virginia DOT
Mitchell Babey	Quality Assurance Engineer Pennsylvania Turnpike Commission
Tom Batz	Manager, Technology Development TRANSCOM
Paul Carris	Manager of Client Services Government and Community Affairs Port Authority New York/New Jersey
Jimmy Chu	Manager, Traffic Management System Virginia DOT
Chandra Clayton	Engineering Programs Supervisor Virginia DOT
Werner (Dutch) Eichorn	Assistant District Traffic Engineer Pennsylvania DOT, District 6
Tom Jennings	Transportation Systems Management Engineer FHWA - Virginia
Steve Kuciemba	Section Chief, Advanced Systems Development Maryland State Highway Administration
James Mona	Transportation Supervisory Engineer Connecticut DOT
Howard Moore	Assistant Administrator Maryland Transportation Authority
John Payne	Acting Chief, Traffic Operations DC. Department of Public Works
Dennis Petti	Principal Construction Engineer New Jersey Highway Authority
Dave Powell	Director, Operations Bureau Off ice of Traffic Engineering and Safety New York State DOT
Tina Troisi	Supervisor, Planning and Programming New York State Thruway Authority

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

APPENDICES

LIST OF FIGURES

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF TABLES

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF ACRONYMS

AAA	American Automobile Association
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average daily Traffic
APTS	Advanced Public Transportation System
ATMS	Advanced Traffic Management Systems
AVC	Automated Vehicle Classification
AVI	Automatic Vehicle Identification
AVL	Automated Vehicle Location
BBO	Buy Build Operate
BBS	Bulletin Board System
BMS	Bridge Management System
BOO	Build Own Operate
BOT	Build Operate Transfer
BTO	Build Transfer Operate
CAD	Computer-aided Dispatch
CalTrans	California Department of Transportation
CAO	Contract Add Operate
CASE	Computer Aided Software Engineering
CCATS	Camera and Computer Aided Traffic Sensor
CCD	Charge Coupled Device
CCTV	Closed Circuit Television
CCU	Central Communications Interface
CEV	Controlled Environment Vault
CLS	Closed Loop System
CMAQ	Congestion Management/Air Quality
CMS	Congestion Management System
CODEC	Coder/Decoder
CVFO	Commercial Vehicle Fleet Operators

CVO	Commercial Vehicle Operations
CW	Continuous Wave
DACS	Digital Access And Crossconnect System
DGPS	Differential GPS
DOT	Department of Transportation
EIA	Electronics Industry Association
EMS	Emergency Medical Services
EPA	Environmental Protection Agency
ETC	Electronic Toll Collection
ETTM	Electronic Toll and Traffic Management
FAA	Federal Aviation Administration
FDM	Frequency Division Multiplex
FHWA	Federal Highway Administration
FLIR	Forward Looking Infrared
FM	Frequency Modulation
FMCW	Frequency Modulated Continuous Wave
FOT	Field Operational Test
FSP	Freeway Service Patrol
FTA	Federal Transit Administration
FTMS	Freeway Traffic Management System
FY	Fiscal Year
GPS	Global Positioning System
HANDAR™	Name of an Environmental Sensor
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HELP	Heavy Vehicle Electronic License Plate Project
HOV	High Occupancy Vehicle
I-95 cc	I-95 Corridor Coalition
I/O	Input/Output
IDEA	Innovations Deserving Exploratory Analysis
IEEE	Institute for Electrical and Electronics Engineering

IEN	Information Exchange Network
IMS	Intermodal Management System
IOC	Initial Operating Capability
IR	Infrared
ISP	Information Service Providers
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation Systems
IVHS	Intelligent Vehicle Highway Systems
LCARTS	Low Cost Advanced Roadway Traffic Sensor
LIDAR	Llght Detection and Ranging
LORAN	LOng Range Aid to Navigation
MOE	Measure of Effectiveness
MPO	Metropolitan Planning Organizations
MSSA	Multi-Sensor Surveillance Aircraft
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NMS	Network Management System
NTCIP	National Traffic Control/IVHS Communications Protocol
NTSC	National Television Standards Committee
O&M	Operations and Maintenance
O-D	Origin-Destination
OBS	Observation Balloon System
PATH	Programs on Advanced Technology for Highways
PMS	Pavement Monitoring System
PTMS	Public Transportation Management System
PTZ	Pan/Tilt/Zoom
R&D	Research and Development
RF	Radio Frequency
RPU	Remote Processing Unit
RSPA	Research and Special Program Administration
RT-TRACS	Real-Time Traffic Adaptive Control System

RTIC	Regional Traffic Information Center
RTMS	Remote Traffic Microwave Sensor
RTPO	Regional Transportation Planning Organizations
SCAN	Surface Conditions ANalyzer
SMS	Safety Management System
SOC	State-wide Operations Center
SONET	Synchronous Optical Network
SOP	Standard Operating Procedure
SOV	Single Occupancy Vehicle
SPVD	Self-Power Vehicle Detector
SR/T	Surveillance Requirements/Technology
STP	Surface Transportation Program
TAR	Traveler Advisory Radio
TAS	Traffic Analysis System
TCM	Transportation Control Measures
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Travel Demand Management
TFWAS	Traffic Flow Wide Area Surveillance
TIS	Traveler Information Services
TMA	Transportation Management Areas
TMC	Traffic Management Center
TMS	Traffic Management System (also Traffic Monitoring System)
TRB	Transportation Research Board
UAV	Unmanned Aerial Vehicle
UPS	Uninterruptable Power Supply
USDOT	United States Department of Transportation
VDC	Vehicle Detector/Classifier
VDOT	Virginia Department of Transportation
VDS	Vehicle Detector Subsystem
VIA	Video Image Analysis
VID	Video Imaging Detection

VIDS	Video Incident Detection System
VLU	Vehicle Location Units
VMS	Variable Message Sign
VMT	Vehicle Miles Traveled
VPD	Vehicle Presence Detectors
VRAM	Video Random Access Memory
VSAT	Very Small Aperture Terminal
VVDS	Video Vehicle Detection Systems
WADS	Wide Area Detection System
WAN	Wide Area Network
WATM	Wide Area Traffic Management
WlM	Weigh-in-Motion

EXECUTIVE SUMMARY

BACKGROUND

The term *surveillance* has been used to denote the observation of conditions in time and space. Thus, the function of a surveillance system in an Intelligent Transportation System (ITS) environment is to provide information of the observed conditions to enable the implementation of traffic management, Travel Demand Management (TDM), and Traveler Information Services (TIS). Although the objectives of transportation management decisions have been to reduce traffic delay and accidents, concerns for the environment have made improvement of environmental quality an additional objective. This addition has expanded the function of a surveillance system to include observation of environmental conditions in time and space. This addition is consistent with the I-95 Corridor Coalition goals derived from its stated mission.

The purpose of this Surveillance Requirements/Technology (SR/T) Project is to develop an implementation plan for a Corridor-wide traffic and environmental surveillance system using state-of-the-art and cost-effective technologies. To fulfill this purpose, the objectives of the Project are:

a. Identify the primary goals of the Corridor-wide Surveillance System.

b. Understand the level and type of surveillance currently available in the Corridor.

c. Understand current state-of-the-art surveillance technologies.

d. Develop the Corridor-wide surveillance system requirements and conceptual design.

e. Estimate the system's cost based on the conceptual system design.

f. Identify potential Field Operational Tests (FOT) for Phase II.

This report summarizes the SR/T Project conducted for the I-95 Corridor Coalition over an 8-month period from September 1994 through May 1995.

SYSTEM GOALS AND OBJECTIVES

A survey of Coalition member agencies was conducted to identify the primary goals for the system and to obtain a consensus of important system objectives. A list of candidate goals and their associated objectives was provided for rating by all agencies in the survey (refer to Table 1). The survey results have indicated that all candidate goals and objectives were relevant for a Corridor-wide surveillance system and therefore adopted as a basis for developing the systems requirements and conceptual design.

Table 1. Identified Corridor-wide Surveillance System Goals and Objectives

Candidate Goals	Candidate Objectives
Enhance traffic incident management	1. Provide data for automated traffic incident detection 2. Provide information for coordinated incident responses 3. Verify traffic incident reports 4. Detect disabled vehicles and assistance requests 5. Assess the severity of traffic incidents 6. Provide continuous tracking of HAZMAT carriers
Enhance real-time traffic control operations	1. Support real-time, traffic adaptive control 2. Enhance HOV control & operations 3. Accommodate priority vehicles 4. Facilitate reversible-lane operations 5. Improve ramp metering 6. Support congestion pricing 7. Accommodate variable speed limit determination
Enhance traffic management during snow storms and other emergencies	1. Support adaptive control 2. Support snow removal scheduling & operations
Improve multi-modal and inter-modal transportation operations	1. Provide traveler security surveillance at transit stops and stations 2. Provide link travel times for transit time of arrival estimates 3. Track transit vehicle location and schedule adherence 4. Provide park-and-ride lot status 5. Provide transit vehicle tracks as probe data 6. Provide passenger loading estimates
Support Traveler Information Services	1. Provide traffic conditions information (e.g., congestion, incident) 2. Provide roadway conditions information (e.g., closure, snow/ice) 3. Provide inter-urban transit information 4. Provide urban transit information 5. Provide parking information
Enhance the transportation systems planning database	1, Provide incident data (location, type, severity) 2. Provide traffic count data 3. Provide delay data 4. Provide VMT data 5. Provide traffic composition data 6. Provide vehicle **O-D** data
Facilitate Travel Demand Management (TDM)strategy implementation	1. Identify traffic congestion locations and levels 2. Characterize traffic demand levels (e.g., V/C vs. time of day) 3. Monitor air quality
Support traffic law and regulation enforcement	1. Provide weight measurements 2. Provide vehicle height and width measurements 3. Determine vehicle occupancy (for HOV) 4. Provide speed measurements

Among the identified system goals, the survey respondents have indicated that the ability of a Corridor-wide surveillance system to enhance traffic incident management is the most important goal. The relative importance of other goals is as illustrated in Figures 1 and 2, which summarize the result of the goal ratings by all respondents.

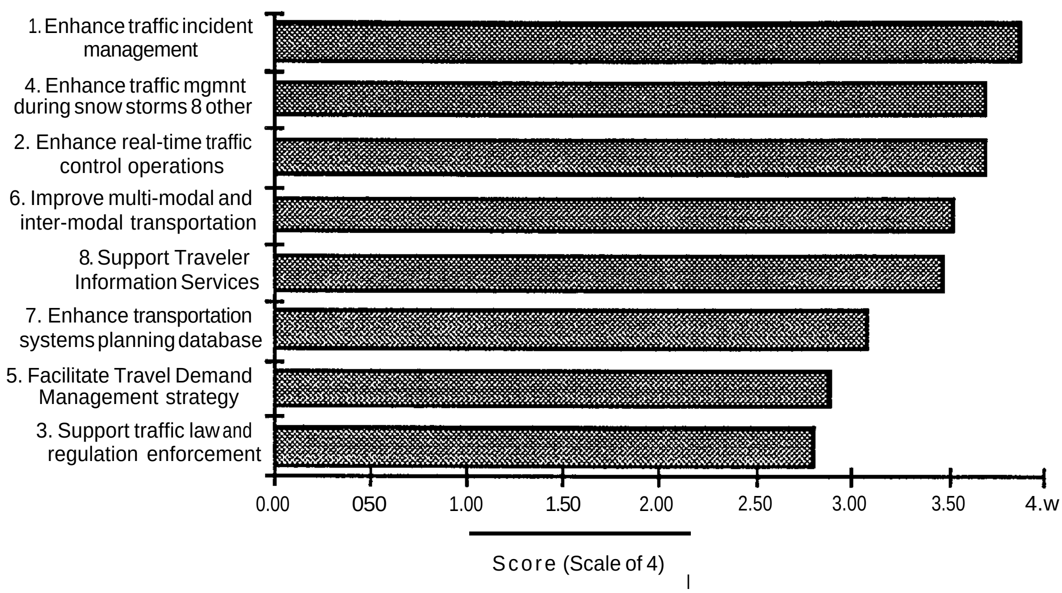

Figure 1. SR/T Goals - Ranking Derived from All Responses

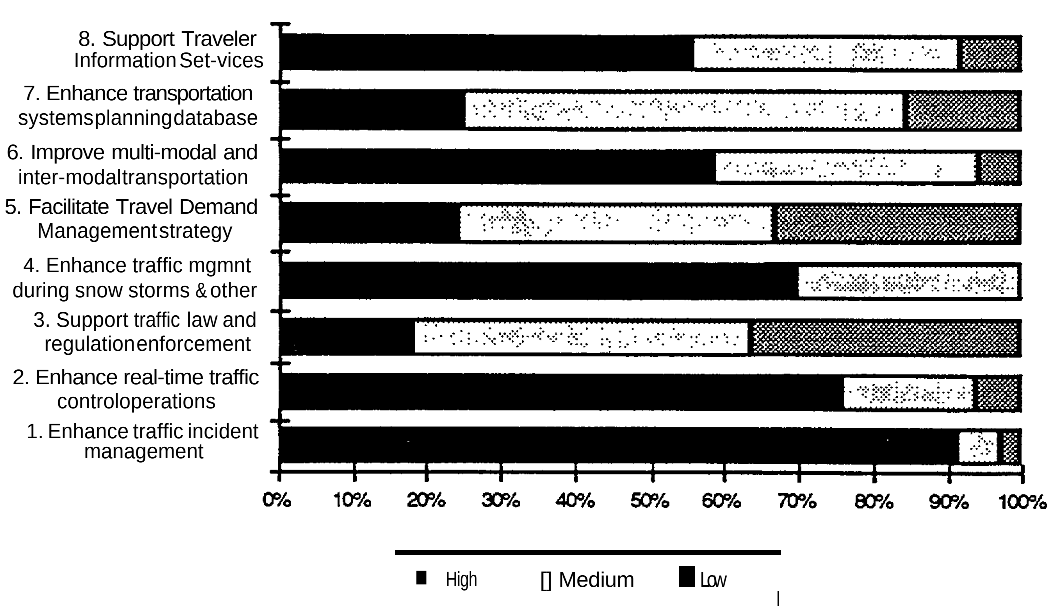

Figure 2. SR/T Goals - Distribution of Responses from All Agencies

The ranking of the system goals was used to develop recommendations for field operational tests and a surveillance system deployment strategy.

SURVEY OF EXISTING SURVEILLANCE IN THE CORRIDOR

Another survey was conducted to determine the level and type of surveillance existing or under development by Coalition member agencies. Of the 26 agencies surveyed, 21 responses were received (81 percent). Some of the received data were incomplete and/or ambiguous, making it impossible to accurately assess the current state of surveillance systems. However, to make the best of the available information, the following summary is provided for illustrative purposes.

a. Approximately 630 miles of Corridor-designated roads were reported as being covered by about 4000 traffic detection devices. In addition, there are about 2700 existing traffic detection devices for which the mileage covered was not reported.

b. Approximately 504 miles of Corridor-designated roads should be covered by a planned deployment of about 3400 traffic detection units. The data does not indicate whether some of this mileage overlaps existing coverage.

If one assumes that the density of traffic detectors (units per mile of road) is uniformly distributed throughout the road network, and that the planned deployment of traffic detection systems would not overlap existing systems, then the estimated existing and planned surveillance coverage would be about 1600 miles, approximately 30 percent of the Study Team's estimated Corridor-designated 5600 miles.

The predominant types of electronic surveillance technologies in use today are inductive loop detectors and CCTVs (refer to Figure 3). The use of CCTVs is expected to increase in the future while that of inductive loops is expected to decrease due to the emergence of radar detectors.

Although electronic surveillance gaps exists, the survey of this Project and that of Project #2 (Incident Management) have shown that human surveillance is used extensively by Coalition member agencies. However, complete detailed information on geographic coverage of human surveillance (such as mileage and frequency) was not available. Human surveillance is expected to play an important role in the future as envisioned by the survey respondents (refer to Figure 4).

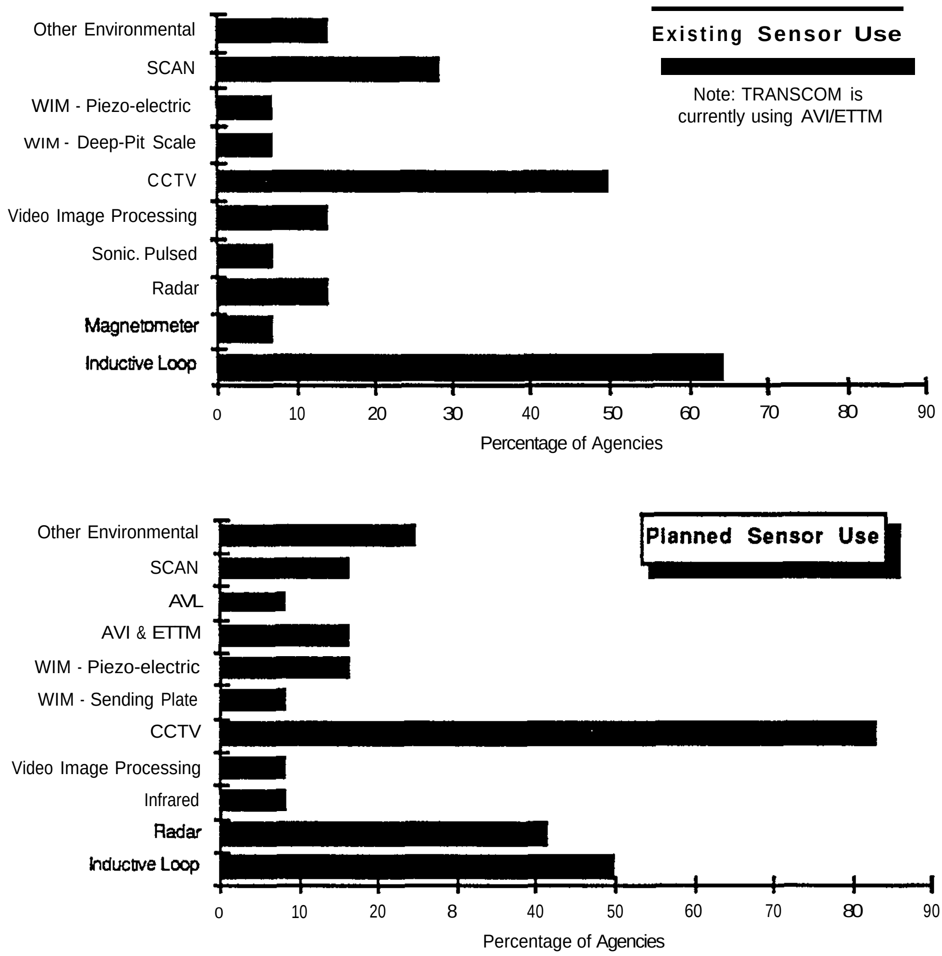

Figure 3. Survey Results for Existing and Planned Sensor Use

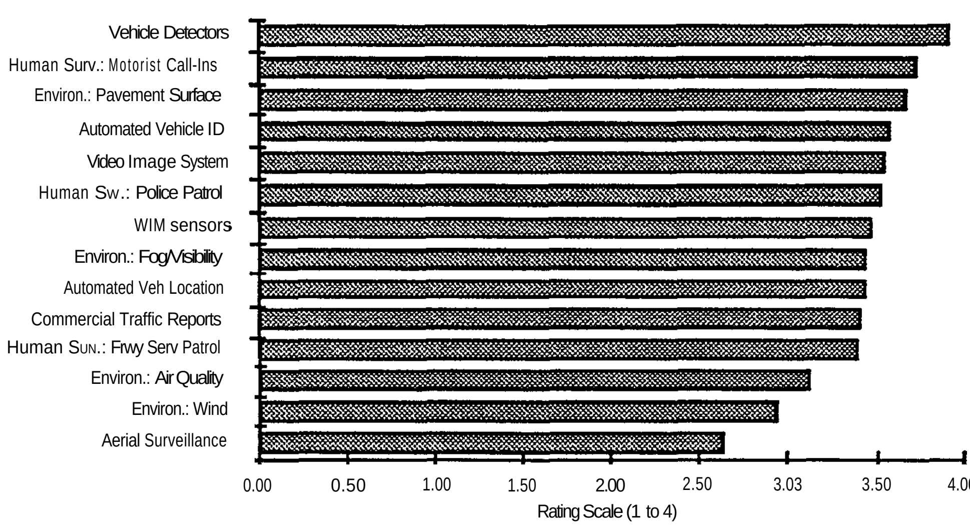

Figure 4. Survey Results of Long-Term Surveillance Technology Vision

STATE-OF-THE-ART SURVEILLANCE TECHNOLOGY REVIEW

A broad range of surveillance and communication technologies were reviewed and assessed. The review covered three major categories of surveillance technologies; traffic detection, environmental conditions sensing, and weigh-in-motion. Each of these categories includes a number of technologies as shown in Table 2.

Table 2. *Surveillance Technologies Reviewed for this Project*

TRAFFIC SURVEILLANCE	VEHICLE WEIGHT SENSING
Inductive Loop Detectors	Bending Plate Systems
Magnetic Detectors and Magnetometers	Shallow Weigh Scales
Sensing Cables, Pressure Plates, and Bending Plates	Deep-Pit Weigh Scales
Infrared/Photoelectric Detectors	Bridge Weighing System
Acoustic Detectors	Capacitive Systems
Microwave Radar Detectors	Piezo-Electric Sensors
Vehicle Probes [Automatic Vehicle Identification (AVI)/Electronic Toll and Traffic Management (ETTM) and Automated Vehicle Location (AVL)]	Fiber-Optic Sensors
	ENVIRONMENTAL CONDITIONS SENSING
	Surface Conditions Analyzer (SCAN)
Video Vehicle Detection Systems	Light Detection and Ranging (LIDAR)
Closed-Circuit Television (CCTV)	HANDAR™.
Aerial Surveillance	

From the reviewed literature, specific information on the alternative surveillance technologies' performance, cost, and deployment experiences was very limited (especially for emerging technologies). Many of these technologies are still being tested and validated, making it difficult to draw any specific conclusion at this time or making meaningful life-cycle cost estimates.

Some of the reviewed literature also suggests that concerns about the potentially negative public reaction to increased exposure to electromagnetic radiation must be addressed to ensure public support of ITS. This would be the case for emerging technologies that use radio frequency or laser as a means for detection.

SURVEILLANCE SYSTEM REQUIREMENTS

Development of I-95 Corridor-wide Surveillance System requirements was based on the system goals and objectives identified by the survey of Coalition member agencies, and on the operational context of the system (see Figure 5) derived from this survey's results.

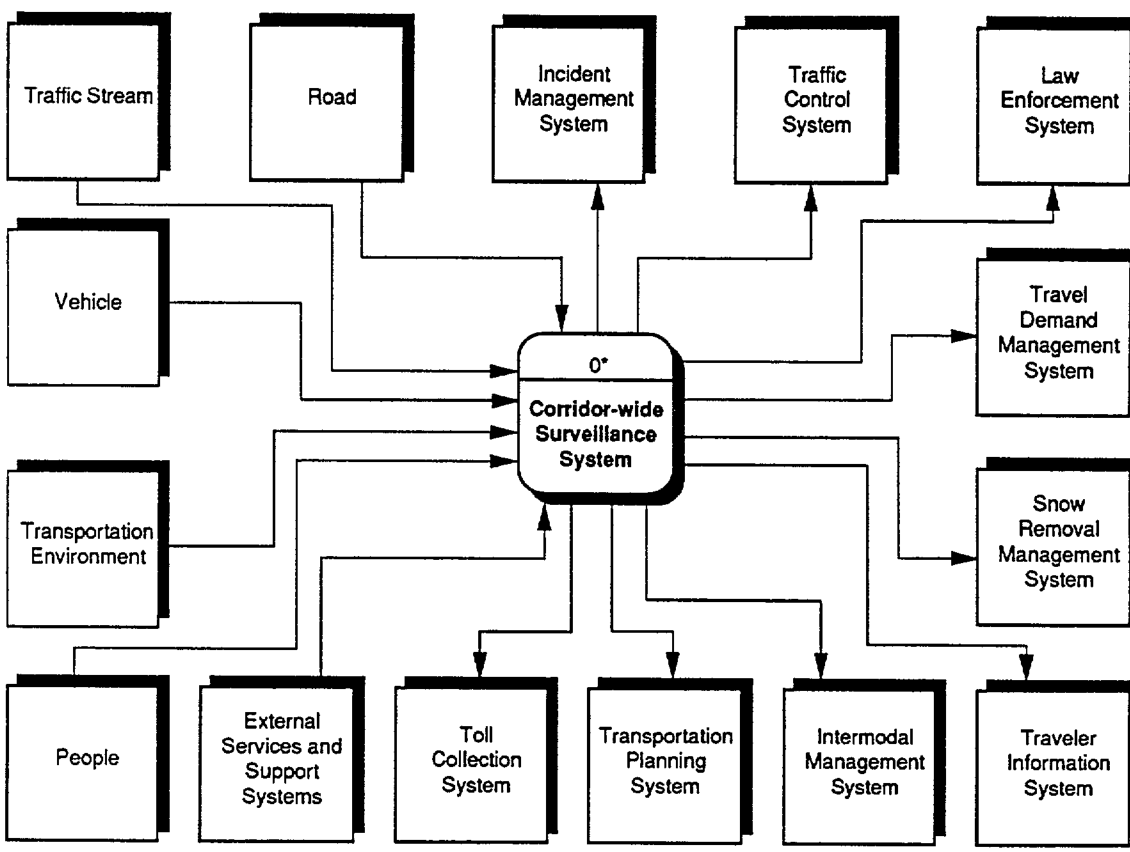

Figure 5. Operational Context of the Corridor-Wide Surveillance System

The system requirements cover operational and functional, interface and communication, and hardware and software aspects. Functional requirements account for the identified system goals and objectives and include the functions and subfunctions shown in Table 3. These functions were decomposed into lower-level functions identifying inputs, outputs, and inter-relationships. The lower-level functions were used to develop a system conceptual design and an operational responsibility framework for participating Coalition member agencies.

Table 3. Summary of Surveillance Functional Requirements

1. Monitor Traffic Conditions 1.1 Acquire Traffic Data' 1.2 Assess Traffic Performance* 1.3 Detect Traffic Incident and Congestion* 1.4 Confirm Traffic Incident and Congestion* 1.5 Acquire Incident Assessment Data' 2. Acquire Individual Vehicle Information 2.1 Determine Vehicle Speed and Direction 2.2 Determine Vehicle Weight and Dimension 2.3 Determine Vehicle Occupancy 2.4 Determine Vehicle Identification 2.5 Determine Vehicle Location 2.6 Determine Vehicle Emissions 2.7 Determine Vehicle Safety 2.8 Receive Vehicle-to-Infrastructure Communications 3. Monitor Environmental Conditions 3.1 Monitor Road Weather Conditions 3.2 Monitor Pavement Temperature 3.3 Formulate Snow/Ice Prediction Data 3.4 Monitor Roadway Air Pollution 3.5 Identify High Pollution Areas 3.6 Formulate Air Quality Assessment Data 4. Monitor Road Hazards 4.1 Detect Debris on Road 4.2 Detect Pavement/Bridge Damage 4.3 Detect Animal Entering Roadway 4.4 Receive Road Hazard Reports 4.5 Identify Low Visibility Conditions 4.6 Detect Slippery Road Conditions 4.7 Detect Hazardous Cross Wind Conditions 4.8 Verify Road Hazard Detection 4.9 Generate Road Hazard Detection Report	5. Monitor Parking Facilities 5.1 Determine Parking Entries and Exits 5.2 Determine Parking Usage 5.3 Formulate Parking Charge Input 6. Monitor Transportation Law Violation 6.1 Determine Speed Violation 6.2 Determine Weight Violation 6.3 Determine Height and Width Violation 6.4 Determine HOV Occupancy Violation 6.5 Determine Designated Route Violation 6.6 Determine Vehicle Emissions Violation 6.7 Determine Unsafe Vehicle Status 7. Monitor Travel Security 7.1 Monitor Intermodal Transfer Points 7.2 Detect Transfer Point Security Events 7.3 Monitor Public Transit Vehicle 7.4 Detect Transit Vehicle Security Events 7.5 Monitor Parking Facility Security 7.6 Detect Parking Facility Security Events 8. Maintain Support Databases 8.1 Maintain Road Network Database 8.2 Maintain Route Database 8.3 Maintain Transfer Point Database 8.4 Maintain Parking Database 8.5 Maintain Surveillance Asset Database 8.6 Maintain Tracked Vehicle Database

*This function is further decomposed to one more level of detail as shown in Section 5.4.2

CONCEPTUAL SYSTEM DESIGN

Because of the geographic characteristics of the Corridor, the conceptual system design was developed for both urban roads and rural roads (see Figures 6 and 7). In either case, the conceptual system design emphasizes integration of surveillance information from multiple sources and use of multiple technology types (including both point detection and wide-area surveillance).

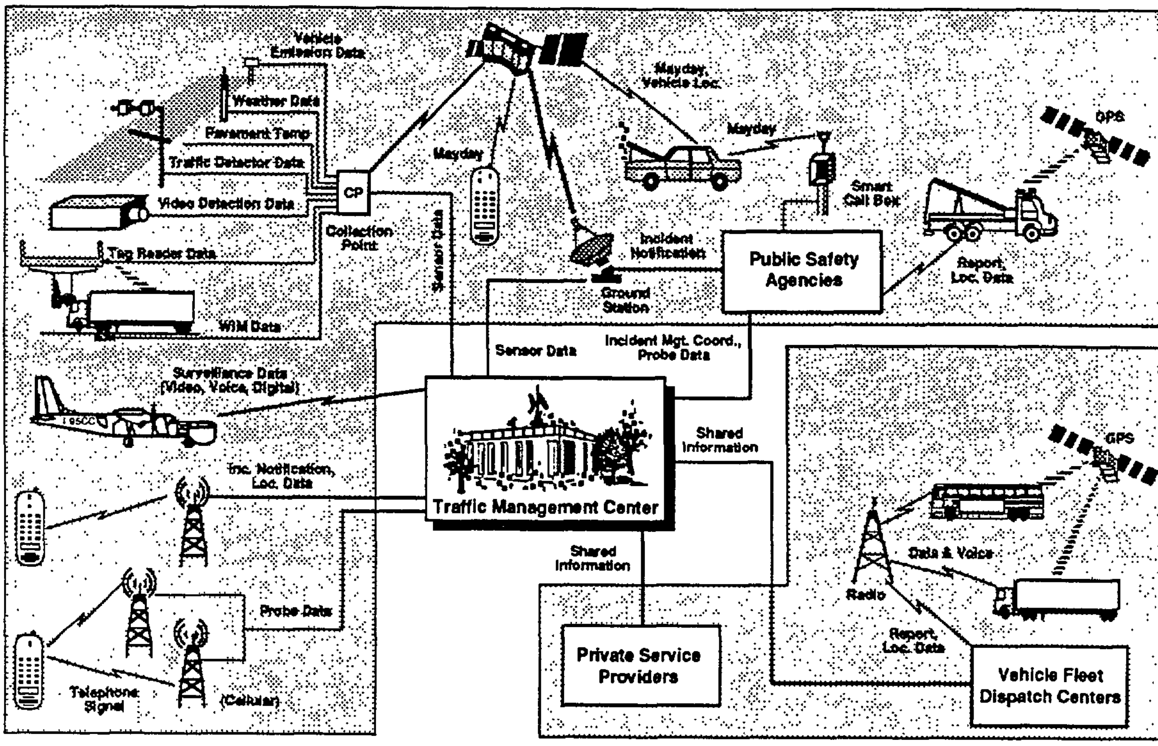

figure 6. Surveillance System Conceptual Design for Urban Roads

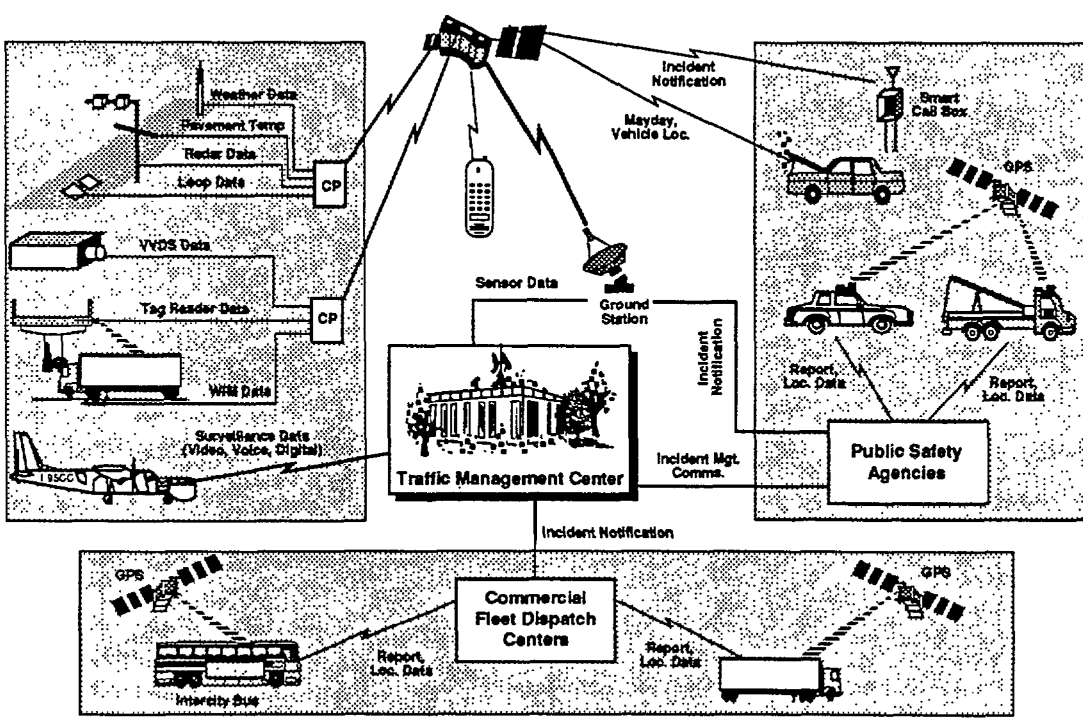

Figure 7. Surveillance System Conceptual Design for Rural Roads

The primary focus of the surveillance concept is to acquire data for traffic incident management, TDM, intermodal transportation, traveler advisory information, and transportation facility planning. To effectively collect data for traffic incident detection and management, additional point detection systems should be installed to fill in the existing surveillance coverage gaps. Overhead or roadside-mounted radar detectors are recommended for new installation though other emerging technologies, such as ultrasonic and infrared, may also be used. The new sensor installations should be integrated with existing inductive loop detectors to provide automated incident detection capability at the local operations center level.

Stand-alone incident detection systems, such as the emerging VVDS, should be installed at locations with a high potential for traffic accidents. Remote incident verification is performed primarily by CCTVs. However, to enhance the ability to quickly verify incidents, the use of a multisensor surveillance aircraft is incorporated. This aircraft should be equipped with a long-range air-to-ground radar and infrared sensors, and should have the capability to maintain an area-wide traffic situational awareness while focusing on acquiring detailed data of an incident. The aircraft should also have the capability to communicate with multiple traffic operations centers and public safety vehicles on the ground, as well as other aerial surveillance assets in the area.

Human surveillance continues to play a major role in incident detection. The design concept includes an ability to receive cellular telephone calls from motorists, and incident notifications from public safety personnel (e.g., police and freeway service patrol vehicle drivers), public transit system operators, and commercial fleet operators. Incident notifications may also be generated by an automated or semi-automated in-vehicle Mayday system interfacing with “Smart Call Boxes” installed along the Corridor’s roadways.

A final source of surveillance information in this conceptual design is vehicle probe data. These sources include vehicle tracking data acquired by public fleet operators (e.g., transit, service patrol, and police vehicles) and commercial fleet operators. Vehicle tracking data may also be acquired through monitoring of cellular telephone signals, interrogating of electronic toll tags, or reading of vehicle license plates.

Tracking transit vehicles will provide probe data for surveillance and supply information for intermodal coordination (transit-to-transit and transit-to-automobile). This system design concept accounts for the information exchange needed to enhance intermodal operations.

In addition to acquiring traffic surveillance data, the acquisition of pavement conditions, weather, and environmental data is incorporated into the design concept.

Because of the lack of and the high cost required to install an adequate surveillance communication infrastructure in the rural areas, the focus of this system design concept is to rely on human surveillance, aerial surveillance, and in-vehicle Mayday notification capability for incident detection. Also, satellite communications would be used to transport data from sensors in remote areas to a nearby TMC for processing.

SYSTEM COST ESTIMATES

The cost estimate effort was not supposed to emphasize the Coalition's required investment in the Corridor-wide Surveillance System; more importantly, it was supposed to emphasize the assumptions and rationale leading to such an estimate. A cost estimate methodology was therefore developed to help the Coalition in future cost analyses. The developed cost methodology contains a detailed description of the assumptions and cost data regarding the unit cost of the surveillance system elements. It also has a cost spread sheet to help analyze changes in system implementation configurations.

To provide an idea of the magnitude of the cost of a new system, a preliminary cost estimation was performed for six scenarios, and the results are summarized in Table 4. The estimation was based on the conceptual system design and assumptions regarding typical spacings of sensors in urban and rural roadway environments. These estimates are by no means conclusive because of the currently assumed levels of system implementation and functionalities, which may vary significantly from one jurisdiction to another depending on the local surveillance goals and needs.

Because of the lack of detailed information on equipment's life-cycle cost (from both the survey returns and the technical literature), the system life-cycle cost could not be estimated within the scope of this Project. However, the methodology and unit cost information gathered for the Project, combined with data from future field operational tests and deployment, can be used to initiate a system life-cycle cost estimation effort.

Table 4. Preliminary **System** *Implementation Cost Under Various Scenarios*

Scenario	Description	Estimated Cost, million $
Baseline	• Complete roadway coverage • Ramp control • Road condition monitoring • WIM sensing • Air quality and weather monitoring • Minimal use of CCTV and AVI systems • Aerial surveillance	2,173
1	Same as Baseline but with full use of CCTV and AVI systems	2,298
2	Same as Baseline but without ramo control	2.027
3	Same as Baseline but without ramp control and roadway condition sensors	2,003
4	Same as Baseline but without ramp control, roadway condition sensors, and WIM sensors	1,981
5	Same as Baseline but without ramp control, roadway condition sensors, WIM sensors, and air quality and weather sensors	1,961

Note: Estimates do not include TMC costs.

RECOMMENDED FIELD OPERATIONAL TEST CANDIDATES

The purpose of FOTs is to evaluate the utility and merit of ITS technologies and services in a real-world setting so as to bridge the gap between R&D and the deployment of proven technologies. To successfully fulfill this purpose for the I-95 Corridor-wide surveillance system, considerations regarding the choice of technologies and the needs of the Coalition must be examined. These considerations were based on the findings of Task 1 (System Goals and Objectives), Task 2 (Existing System Inventory), Task 3 (Technology Assessment), and Task 4 (Systems Requirements and Conceptual Design) of this Project; and they include three main categories: technology, institutional and organizational arrangement, and multiproject integration. The technology consideration reveals that the Coalition should focus on testing technologies that may have region-wide application and impact, as opposed to those that may have only local impact and can be tested outside the Corridor. The institutional consideration indicates the need to identify, understand, and resolve non-technical issues related to the integration and sharing of surveillance information among the agencies (public-public partnership), and between the public sector and the private sector (public-private partnership). The resolution to these issues are essential to the success of the developed system conceptual design. Finally, the multiproject integration consideration emphasizes the need for the surveillance FOTs to be integrated with other FOTs or ITS services. This integration will not only offer a more efficient use of the Coalition's FOT resources, but also will provide an opportunity to conduct an end-to-end evaluation of an integrated intelligent transportation system. The latter is important because the benefits offered by the surveillance system can be more meaningfully evaluated.

The Corridor-wide surveillance FOT program is intended to be a multi-year program that focuses on testing new technologies and coordinated operational procedures. The thrust of the program is to provide surveillance information to support incident management, intermodal coordination, and traveler information applications. The objectives of the Surveillance FOT Program include:

+ Assessing the feasibility of integrating surveillance information from multiple sources. These sources may include existing surveillance assets, new technologies, public agencies, and private organizations.
+ Identifying and formulating institutional arrangements that would enhance the cooperation among agencies and organizations participating in the collection and use of surveillance information.
+ Determining the most feasible technology or technologies that may be deployed Corridor-wide.
+ Gaining the necessary information for the Coalition to prepare its Corridor-wide Surveillance System Deployment Plan.

The recommended FOT Program consists of nine projects as described below. Of the nine projects, the Region-wide Information Integration Project provides the mechanism to tie all of the other projects together and serves as a catalyst for integrating other I-95 Corridor Coalition projects into a seamless Corridor-wide ITS.

1. <u>Project S.1: Region-wide Information Integration</u>, This project's objective is to create and validate a mechanism for fusing surveillance data from multiple sources and organizations. The data will be supplied by systems of other FOT projects or agencies and by the existing surveillance assets. The fused data will be available for use by all ITS applications (e.g., TIS, commercial vehicle operations, and incident management).

2. Project S.2: Service Patrol Vehicle Probe Integration. For this project, AVL and two-way, voice and data communication equipment will be installed on service patrol vehicles (most patrol vehicles may already have two-way, voice communication equipment). The vehicle location data provided by the AVL system will be used to support incident management and vehicle fleet management functions, while the vehicle tracking data will provide probe information for surveillance. The results of this test will help to determine the feasibility to expand the service patrol operations Corridor-wide.

3. Project S.3: Cellular Telephone Traffic Probe Integration. If the currently tested system in the Washington, D.C. area is technically feasible, this recommended test will focus on the technical and institutional data integration issues for a Corridor-wide deployment of the system.

4. Project S.4: Transit Vehicle Probe Integration. Many transit properties in the Corridor use or plan to use AVL technologies to track their vehicles. For vehicles traveling along the Corridor-designated roads, tracking data may be used as surveillance probe data. The purpose of this FOT project is to test the integration of transit vehicle probe data with other surveillance data and to assess opportunities to enhance intermodal coordination.

5. Project S.5: Public/Private Surveillance Information Exchange. This project is to assess the feasibility of collaborating with private organizations that collect traffic surveillance data for their ITS services. Besides the technical feasibility, institutional issues regarding public/private partnership will be examined.

6. Project S.6: Multi-Sensor Surveillance Aircraft. The purpose of this recommended FOT is to assess the feasibility of using a multi-sensor surveillance aircraft for regional traffic surveillance. The aircraft's ability to complement other land-based traffic surveillance systems will be examined.

7. Project S.7: Aerostat Traffic Surveillance. This system's sensor suite is similar to that of the multi-sensor surveillance aircraft and can provide continuous, long-range surveillance coverage. The purpose of this project is to assess the feasibility of the aerostat surveillance system and its complementary aspects to other systems.

8. Project S.8: "Wide-Area" Land-Based Radar Sensor. This sensor technology offers a larger surveillance coverage than many existing point detection systems. The

sensor's output may be used to detect traffic congestion and accurately determine congestion locations. The purpose of this project is to test the feasibility of this radar under urban and rural conditions.

9. Project S.9: Road Weather Information Integration. Road Weather Information Systems (RWIS) are currently used by many member agencies. The purpose of this test is to assess the feasibility of combining RWIS data with other traffic surveillance data to generate winter travel advisory information.

RECOMMENDED FUTURE ACTIONS

Continuing work for the SR/T Project will encompass surveillance technology operational tests and surveillance system deployment to meet Coalition objectives. To support this work, the following recommendations are summarized:

Immediate Actions

+ Development of an ITS architecture for the I-95 Corridor Coalition is recommended. This architecture will provide a framework for integrating all relevant I-95 Corridor Coalition Projects already defined or to be defined based on the Coalition's vision.

+ A prototype of the proposed Region-wide Information Integration System is recommended. This prototype will further explore the potential technical and institutional issues of the Corridor-wide Surveillance System.

+ A consensus-building effort among Coalition member agencies on the recommended Corridor-wide Surveillance System is recommended. This consensus will pave the way to successful system deployment.

+ Development of a detailed Surveillance FOT Program Plan is recommended. This plan will address the issues of where, when, and how each recommended Surveillance FOT project may be implemented.

FOT Implementation Process

+ It is recommended that FOT solicitations for specific groups of Corridor-wide Surveillance System functions be prepared. This will enable potential respondents to understand the system's requirements and to propose creative solutions to meet the Corridor's needs.

+ It is recommended that a transition team be formed to assist in the planning, design, and possibly evaluation of the FOTs. This team will help to exploit the full potential of the evaluated technologies to meet the surveillance system requirements.

Deployment Preparatlon

+ It is recommended that a traffic study be conducted to assess in detail and prioritize areas within the Corridor requiring surveillance coverage. This study will provide the necessary information for developing a detailed system deployment plan.

+ Continual monitoring and periodic assessment of surveillance technologies is recommended. Particular attention should be paid to wide-area surveillance technologies, because they may provide cost-effective solutions to meet the Corridor's needs.

+ The cost database produced in this Project should be refined and updated periodically. This database will be useful for future cost analyses of the Corridor-wide Surveillance System as the Coalition moves toward deployment.

CLOSING REMARKS

System development is a continuing process and evolves over the entire duration of a system. The work accomplished in this Project represents only one of the many steps in this development cycle. Because the concept of the Corridor-wide Surveillance System is based on the partnership principles of the Coalition, the initial steps in the development cycle become even more important to achieve consensus among Coalition members. Consensus is essential if the system development is to move forward. Understanding this, the Study Team has attempted **to** provide a total system view of the Coalition's surveillance needs and the methodology and assumptions leading to the products specified in the Project's Scope of Work. This approach should enable the Corridor-wide Surveillance System to evolve into the 21st Century.

CHAPTER 1
INTRODUCTION

This Report summarizes the results of the Surveillance Requirements/Technology (SR/T) Project conducted for the l-95 Corridor Coalition. The purpose of this Project was to develop a set of Corridor-wide Surveillance System requirements and a system conceptual design to support the desired Intelligent Transportation System (ITS) services of the Corridor. This Project, also known as Project #3, was conducted over an 8-month period from September 1994 through May 1995.

The need for the SR/T Project may be examined from two perspectives; ITS functional perspective and Coalition partnership perspective. Each of these perspectives is discussed in this Chapter as a prelude to a detailed description of the work accomplished for the Project. Also provided is an overview of the Project and a description of the Report's organization.

1.1 "ITS" FUNCTIONAL PERSPECTIVE OF SURVEILLANCE

The term surveillance has been used to denote the observation of conditions in time and space. The function of a surveillance system is, thus, to provide information of the observed conditions to enable the implementation of other functions or services. In the context of ITS, surveillance information is necessary to enable the implementation of traffic management functions, travel demand management functions, and traveler information services. The role of a surveillance system in an automated highway system, however, is not yet explored at this time because of the long-term nature of this concept.

The focus of traffic management is to increase the operational efficiency of the transportation network. To accomplish this, traffic management functions require reliable, accurate, and timely traffic conditions information, Such information is necessary to detect traffic incident and congestion, implement appropriate incident response actions, implement traffic control strategies, and monitor network flows. With today's advances in traffic control technologies, real-time surveillance information becomes essential.

Travel Demand Management (TDM) is typically a public policy issue, and is driven by congestion management practices and environmental concerns and regulations. The goal of TDM is to reduce vehicle demands on the roadway by developing and encouraging the use of other modes of transportation besides the Single Occupancy Vehicle (SOV), the changes in departure times (e.g., staggered work hours), or even the elemination of some trips (e.g., telecommuting). TDM practices may include programs such as congestion pricing, reversible HOV lanes, and signal priorities for mass transit vehicles. These practices require multi-modal transportation information in addition to environmental data (e.g., air quality) and travel security surveillance information (to encourage inter-modal usage). Thus, in the context of ITS, the role of a surveillance system would no longer be confined within the traffic management domain.

The third element, Traveler information Services (TIS), provides real-time traffic and travel conditions information to the traveling public (including fleet operators) to help them make informed travel choices. The objectives of TIS is to assist travelers reaching their destination safely and efficiently. Traveler information services may include multi-modal trip planning, route guidance (for commercial, non-commercial, and emergency-response vehicle drivers), and driver advisory (e.g., potential road hazards). These services require information such as traffic conditions, incidents, construction, road hazards, parking availability, weather conditions, etc., from a surveillance system.

The above functional view of a surveillance system in ITS manifests only one aspect of the need for this SR/T Project. The other aspect, as described below, is the nature of the I-95 Corridor Coalition itself.

1.2 COALITION PARTNERSHIP PERSPECTIVE OF SURVEILLANCE

Surveillance has traditionally been centered on collecting traffic information for a specific locality or jurisdiction. Typically, each jurisdiction operates its own surveillance system to acquire, process, and disseminate data to support its traffic management and control, and traveler information needs. With the increasing traffic demand, an inability to significantly expand highway capacity, and degrading environmental quality, the need for coordinated transportation management and control across multiple jurisdictions arises. To meet this need and its associated challenges, the I-95 Corridor Coalition was formed in 1992.

The i-95 Northeast Corridor, one of four Priority Corridors in the country designated by the U.S. Department of Transportation (US DOT), has one of the nation's most traveled road networks and hosts over 25 percent of the U.S. population. The I-95 Corridor Coalition currently consists of 12

Departments of Transportation stretching from Maine to Virginia, 12 Toll Authorities within the Corridor, the Transportation Departments of Washington D.C. and New York City, and 11 affiliated organizations as shown in Table 1-1.

Table 1-1. *1-95 Corridor Coalition Membership (as of 7994)*

12 Transportatlon Authorities	14 State/Local DOTs	11 Affiliated Organizations
Delaware River and Bay Authority	Connecticut	AAA Foundation for Traffic Safety
Delaware River Port Authority	Delaware	American Bus Association
Delaware Turnpike Administration	District of Columbia	AMTRAK
Maine Turnpike Authority	Maine	ATA Foundation
Maryland Transportation Authority	Maryland	Federal Highway Administration
Massachusetts Turnpike Authority	Massachusetts	Federal Railroad Administration
New Jersey Highway Authority	New Hampshire	Federal Transit Administration
New Jersey Turnpike Authority	New Jersey	ITS America
New York State Thruway	New York City	National Private Truck Council
Pennsylvania Turnpike Commission	New York	TRANSCOM
Port Authority of New York/New Jersey	Pennsylvania	USDOT Office of lntermodalism
Triborough Bridge and Tunnel Authority	Rhode Island	
	Vermont	
	Virginia	

The I-95 Corridor Coalition is a partnership of public and private transportation agencies and organizations to provide a seamless, state-of-the-art multi-modal transportation system to promote mobility, efficiency, and safety of both passenger and goods transportation in the Corridor. The Coalition operates on the principle of cooperative coordination among its members. This principle has led to an ITS vision of not one master system operated by a single entity.It is rather a series of local systems, each planned, designed, implemented, and operated in close coordination with the others while remaining under the jurisdiction of individual states or operating authorities.

To properly serve into this vision, the thrust of the I-95 Corridor-wide Surveillance System is not necessarily the development of new surveillance systems; but rather providing the technological linkages among existing and future systems, and organizational linkages among member agencies to effectively enhance inter-jurisdictional transportation system management functions.

1.3 PROJECT PURPOSE AND OBJECTIVES

The purpose of this project is to develop an implementation plan for a Corridor-wide traffic surveillance and environmental monitoring system using state-of-the-art and cost-effective technologies. This system is planned for a 20-year horizon and provides a platform to develop, test, and deploy advanced surveillance technologies, and to integrate private sector initiatives providing ITS services in the Corridor.

To fulfill the above purpose, the objectives of the Project are:

- Identify the primary goals for the Corridor-wide Surveillance System, including reaching consensus concerning the most mutually important system objectives.
- Understand the level and type of surveillance currently available in the Corridor.
- Understand the current state-of-the-art surveillance technologies that may be suitable for Corridor-wide applications.
- Develop a set of system requirements and a conceptual system design to meet the Coalition's surveillance needs.
- Estimate the cost of the system based on the conceptual system design.
- Identify a series of potential field operational tests (FOTs) through which the alternative surveillance technologies and system operational procedures can be evaluated and validated.

This Project represents Phase I (implementation planning) of the Coalition's effort to develop a Corridor-wide Surveillance System. Phase II of the effort, should it be approved, would be the implementation of the feasible FOTs to validate key concepts of the system.

1.4 PROJECT TASKS

The SR/T Project is composed of seven tasks (as shown in Figure l-l) with Task 7 being the development of this Final Project Report. A brief description of each of the six technical tasks is provided in the following paragraphs.

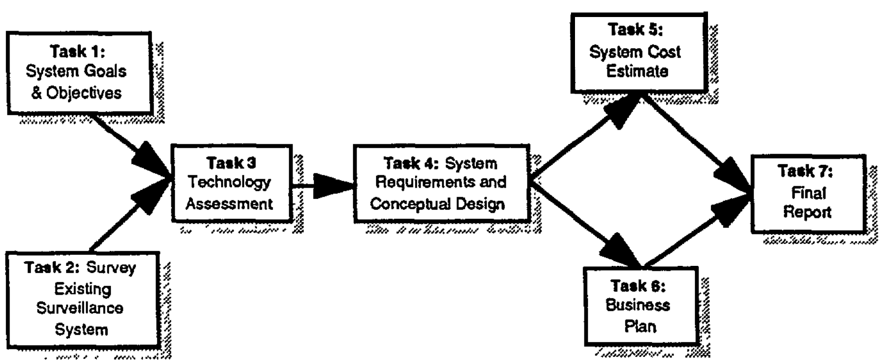

Figure 1-1. The Seven Tasks of the SR/T Project

Task 1: System Goals and Objectives. A survey of Coalition members was conducted to identify the goals and objectives for the Corridor-wide Surveillance System. The results of this survey have been used as a basis for developing the system requirements and conceptual design.

Task 2: Survey Existing Surveillance Systems. An inventory of the existing level and type of surveillance within the Corridor was conducted in conjunction with an identification of planned systems. The results of this effort were used to assess the surveillance coverage needs of the Corridor.

Task 3: Technology Assessment- A review of existing and emerging surveillance and communications technologies was conducted in this task. The reviewed technologies cover three categories; traffic detectors, vehicle weight sensors, and environmental sensors. The advantages and disadvantages of alternative technologies in each category were assessed to provide a basis for technology selection in the system conceptual design.

Task 4: System Requirements and Conceptual Design. This task, based on the results of Tasks 1 to 3, developed a comprehensive set of functional, communications, interface, software, and hardware requirements for a Corridor-wide Surveillance System. Based on these requirements a conceptual system design was developed for urban and rural roads in the Corridor, taking into consideration the existing surveillance system characteristics and the results of the technology assessment.

Task 5: System Cost Estimate. Cost estimates of the conceptual Corridor-wide Surveillance System were made in this task. They include estimates of software, communication and interfaces, surveillance system hardware, computers and peripherals , public interaction, training and staffing, and start-up and operation costs. A cost-estimate spreadsheet was also prepared for documenting the cost elements and computing the overall system costs.

Task 6: Business Plan. A Business Plan was developed in this Task. This Plan provides recommendations for a series of FOTs and a discussion on issues related to the implementation of a Corridor-wide Surveillance System. The major components of the SR/T Business Plan are:

+ Potential field operational tests recommended for Phase II.
+ Funding opportunities and alternative cost-sharing schemes among agencies.
+ Estimated system deployment and cost schedule.
+ Potential public/private co-venture opportunities in surveillance.
+ A budget plan for system operation and maintenance.

1.5 RELATIONSHIP WITH OTHER COALITION'S PROJECTS

The I-95 Corridor Coalition's Business Plan contains 21 projects representing the current ITS effort of the Coalition (refer to Table 1-2). These projects are grouped into three categories; Internal Coalition Operations, Customer/User Services, and Special Studies and Surveys. The Surveillance Requirements/Technology Project falls under the category of Special Studies and Surveys.

Table 1-2. I-95 Corridor Coalition Projects

internal Coalition Operations	Customer/User Services	Special Studies and Surveys
1. Information Exchange Network	2. Incident Management'	3. Surveillance Requirements/Technology*
6. User Needs and Marketability*	4. Commercial Vehicle Operations'	5. Public/Private Sector Outreach*
7. Consultant Support Services*	8. Traveler Information Services*	11. Technology Exchange and Training Program
9. Coordinated VMS/HAR System*	15. Corridor-wide AVI/ETTM Feasibility	13. Passenger/Freight Supply and Demand Analysis
10. Communication Infrastructure Opportunities	18. Emergency Response System	14. Institutional Barriers and Issues.
12. Intermodal Outreach and Information Exchange	19. Rural "MAYDAY"/800 Call-in System	
16. Feasibility of Regional Communications Centers	21. Automated Highway System Corridor Identification	
17. Long-Range Strategic Plan'		
20. Corridor-wide Decision Support/Expert System		

• Projects that have been initiated and conducted concurrently with this SR/T Project

Among the initiated projects, the SR/T Project (#3) is closely related to seven other ongoing projects as shown in Table 1-3. Because of these relationships inter-project coordination have been conducted and will need to continue into the field operational testing in Phase II.

Table 1-3. Relationships of the SR/T Project with Other Ongoing Projects

Project Name	Relationship
Information Exchange Network (#1)	This project requires an understanding of the data communication needs of the surveillance system to define the information exchange network that links all Coalition member agencies.
# Incident Management - Detection, Response, and Operations (#2)	Incident detection and verification information requirements of this Project affect the surveillance functional requirements.
Commercial Vehicle Operation (#4)	The weight and vehicle tracking functions are similar to those of the surveillance system.
Public/Private Sector Outreach (#5)	Uses SR/T Proiect's results for investigating partnership issues
Traveler Information Services (#8)	This project has some similar information requirements and public/private partnership principles as those of the SR/T Project.
Coordinated VMS/HAR System(#9)	Common communication links will be used for VMS/HAR as well as surveillance in most cases.
Long-Range Strategic Plan (#17)	Uses SR/T Project's results for strategic planning.

In addition to the above on-going projects, the SR/T Project also has relationships with other Coalition's projects that are yet to begin as shown in Table 1-4.

Table 1-4. Relationships of theSR/T Project with Future Projects

Project Name	Relationship
Communication Infrastructure Opportunities (#10)	This project defines the cost of communications for both ATIS and ATMS functions. New technologies, together with opportunities to "piggy" back with other public agencies or private-sector communications provide opportunities for cost savings in the surveillance system.
Technology Exchange and Training Program (#11)	This project will develop a technology exchange and training program for Coalition agencies. The technologies to be used in the surveillance system will help to determine the surveillance training needs for this project.
Intermodal Outreach and Information Exchange (#12)	An objective of this project is to define opportunities for intermodal information exchange. Since many modal agencies (e.g., transit) can contribute their data to be used as surveillance information, these opportunities should be examined in the light of the surveillance system concepts defined in this SR/T Project
Passenger/Freight Supply and Demand Analysis (#13)	This project involves the use of existing sources to compile information and statistics on network characteristics and passenger and freight statistics in the I-95 Corridor. Assets from the Corridor-wide Surveillance System may be utilized for this purpose and should be reviewed.
Institutional Barriers and Issues (#14)	Issues related to surveillance information sharing (e.g., organizational privacy) and public/private partnership in surveillance data collection should be examined by this Project.
Corridor-wide AVI/ETTM Feasibility (#15)	This project is aimed at developing a coordinated Corridor-wide AVI/ETTM system. AVI/ETTM equipped facilities could potentially provide supplemental surveillance information to the Corridor-wide Surveillance System.
Emergency Response System (#18)	The methods to detect and respond to driver emergencies may have a potential to contribute to the data collection functions of the surveillance system. These methods should be reviewed for possible incorporation into the surveillance system to minimize investment requirements.
Rural Mayday/800 Call-In System (#19)	This project involves an operational test of a rural 800 number for calling in incidents on more remote portions of the network. It is combined with a Mayday and traveler phone mail system. The information from this system needs to be incorporated into the Corridor-wide Surveillance System.
Corridor-wide Decision Support/Expert System (#20)	This project addresses the anticipated complexities that will arise as more and more incidents are dealt with across jurisdictional boundaries. The requirements defined for the Corridor-wide Surveillance System may be used to assess the decision/expert system needs.

1.6 ORGANIZATION OF THE REPORT

This report is organized according to the logical flow of the tasks performed during the study. The report contains 9 Chapters as identified below:

+ Chapter 2: System Goals and Objectives.
+ Chapter 3: System inventory.
+ Chapter 4: Technology Assessment.
+ Chapter 5: System Requirements.
+ Chapter 6: Conceptual System Design.
+ Chapter 7: System Cost Estimates.
+ Chapter 8: Business Plan.
+ Chapter 9: Conclusion.

In addition to those chapters, a number of appendices are also provided at the end of the report.

CHAPTER 2
GOALS AND OBJECTIVES

This Chapter summarizes the results of the goals and objectives survey conducted for Task 1 of the study. The purpose of the survey was to identify a unified set of goals and objectives for a Corridor-wide surveillance system. Task objectives, therefore, include the following:

+ Conduct a survey among the Coalition members to determine their individual goals and objectives for short- and long-term surveillance.
+ Understand surveillance information needs and use by Coalition member agencies.
+ Understand the surveillance visions of Coalition member agencies.
+ Identify and prioritize the mutually important system goals and objectives.
+ Seek consensus among the Coalition members on the identified goals and objectives.
+ Solicit input from the private sector to system goals and objectives.

The goals and objectives derived from this task acted as key to the success of the whole project, because they were the foundation upon which the systems requirements and conceptual design were later specified.

The goals and objectives survey was conducted according to the following four steps (see Figure 2-1):

a. Define the context of a Corridor-wide surveillance system. This definition encompassed perspectives of the various system functions, agencies' jurisdictional roles and responsibilities, influences of federal regulations and initiatives, and available technologies.

b. Identify system goals and objectives using a questionnaire survey and interviews with Coalition members and private organizations who were considered to be potential ITS service providers in the Corridor.

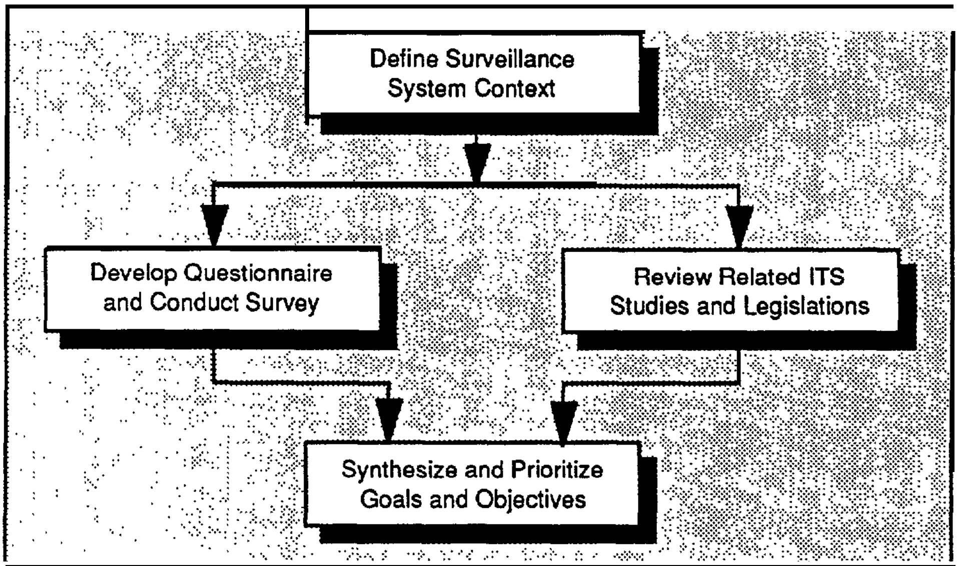

Figure 2-1. Four-Step Approach to Task 1

c. Identify system goals and objectives based on literature review. This review of national, state, and regional ITS efforts provided additional information to ensure consistency of the developed goals and objectives with national, state, and regional directions.

d. Synthesize and recommend surveillance system goals and objectives. Based on the information gathered from steps a., b., and c., a unified set of goals and objectives was developed and recommended. These goals and objectives were also ranked to guide future development of an implementation plan.

This Chapter is organized to follow the logical flow of steps a. through d. described above. Section 2.1 describes the surveillance system context. Section 2.2 presents the approach to and the results of the questionnaire survey. Section 2.3 provides a summary of the ITS literature governing surveillance system goals and objectives. Section 2.4 presents the recommended goals and objectives from which system requirements may be derived.

2.1 SURVEILLANCE SYSTEM CONTEXT

Surveillance needs have traditionally been centered on collecting traffic information for detecting and mitigating the effects of incidents and recurring congestion. The I-95 Corridor Coalition, with its diverse members operating various transportation modes, presents a challenge and an opportunity to broaden the focus of a corridor-wide surveillance system. Each transportation mode has its own information needs as well as capabilities to contributing to the Corridor's overall surveillance picture of the transportation system. Thus, to properly identify the goals and objectives for a corridor-wide surveillance system, these needs and capabilities should be explored and understood. In addition, the constraints and issues associated with development of such a surveillance system should be identified to help formulate realistic goals and objectives. The purpose of this section is to describe these considerations within the context of multi-modal transportation, jurisdictional and operational structure, federal legislation, and system function and technology.

2.1 .1 Multi-modal Transportation Context

Private Vehicles

The primary objective of traffic management is to facilitate the smooth flow of all traffic through a region or municipality. To fulfill this objective, accurate and timely traffic surveillance data is required. Within the context of the I-95 Corridor, surveillance data regarding recurrent and non-recurrent congestion along major highways is needed to help private vehicle users to avoid traffic congestion before their trips begin and while en route. This data must be of consistent levels of detail and format to ensure compatibility from one jurisdiction to another. Furthermore, with the current ITS initiatives to provide in-vehicle signing information (especially safety-related), surveillance data compatibility will become more important to motorists traveling across many jurisdictions within the Corridor.

Private vehicles not only receive surveillance information to enhance traffic safety and travel efficiency, but also can contribute to surveillance data collection. A typical example is probe data provided through Automated Vehicle Identification (AVI), such as electronic toll collection or Automated Vehicle Location (AVL) technologies. As these technologies mature and are widely deployed throughout the Corridor, probe data will be a major part of the surveillance information and should be considered in the conceptual design.

Commercial Trucks

The performance of the trucking industry depends on its ability to deliver fast, economical, and dependable service to its customers. Hence, accurate information regarding traffic congestion and the availability of alternate routes is valued highly. Truck operators commonly share information about traffic conditions and exchange route guidance information with each other by radio. However, this information is often of dubious value and cannot incorporate the area-wide knowledge of traffic information obtained by a Corridor-wide surveillance system.

With respect to in-vehicle signing, surveillance data compatibility within the Corridor should be maintained for commercial trucks. Furthermore, the surveillance data should be specific to provide warnings consistent with the operational characteristics of the vehicles (e.g., accelerating, decelerating, braking, and maneuvering).

The trucking industry also offers the potential to provide valuable surveillance data for traffic management. By using AVI systems such as those deployed in the HELP/Crescent and Advantage I-75 Programs, probe data from commercial vehicles may be provided.

Transit (Regional and Intercity Bus and Rail)

The performance of a public transit system depends to a large extent on maximizing its ridership. To achieve this objective, transit service providers must create strong incentives for people to shift mode by demonstrating reliable, economical, and convenient service with a reduction in overall trip time. Bus transit service providers can use traffic surveillance information to implement temporary route deviation as necessary to maintain schedule, or to more accurately predict the vehicles' times of arrival at transit stops and transfer points to inform their customers.

Within the I-95 Corridor, surveillance information will benefit both the transit services that connect major inter-modal transfer points (such as Amtrak stations and airports) with the local business districts, and those transit services with parts of their routes on the Corridor's defined highway network. The ability of the local transit systems to effectively serve the inter-city rail and air passengers is crucial to achieve the traffic reduction and air quality goals in major metropolitan areas in the Corridor. Approximately 28 percent of all inter-city passenger trips in the Corridor are made by rail and air modes, or about 18 million person trips per year [Booz-Allen and Hamilton, 1989].

Today, many transit properties are installing AVL equipment on their vehicles along with computer-aided dispatch systems to enhance their fleet management capability. Such systems can provide probe data (almost as a by-product) to augment the traffic surveillance information. In addition, with proper coordination, location-specific driver reports of traffic conditions (in both the peak and off -peak directions) may be made available through the transit control center.

Paratransit

Paratransit services offer demand responsive transportation to improve accessibility to other transportation modes such as commuter rail and inter-city rail services. Demand responsive services with either random-route (i.e., random pick-up and drop-off points) or flexible-route (i.e., temporary deviation from a fixed route for passenger pick-ups and drop-offs) operations require accurate real-time link travel time data to optimize dispatching and maximize schedule adherence. Because the movements of many modern paratransit vehicles are tracked within the service area, vehicle probe data may be derived to supplement surveillance information.

Air Travel

Coordinated management of airport "air-side" and "land-side" operations is increasingly attracting attention and effort. Airline scheduling and reservation information can be used to anticipate and manage the demand on the land-side operations: that is, airport ingress, egress, and parking. This information is also valuable to regional traffic operations systems. In addition, coordinating land-side and air-side operations presents opportunities for providing pre-trip and en route information to motorists regarding air traffic delays or changes in flight status. On the other hand, the surveillance information local to the airport can assist arriving passengers to make informed travel choices for their trips.

2.1.2 Jurisdictional and Operational Context

Differences in jurisdictional responsibilities, revenue generation capabilities, and operational procedures in the I-95 Corridor present many challenges for developing and implementing a corridor-wide surveillance system. These challenges must be put in a context that can guide identification of and consensus building for surveillance system goals and objectives. The following paragraphs briefly describe these challenges.

Technology Standardization

Technology standardization is a major concern of all ITS initiatives. The I-95 Corridor Coalition has reflected this concern in its vision and objectives, especially in the following [I-95 Corridor Coalition, June 1994]:

> "Coordinate the management of facilities and the delivery of traffic/travel information across jurisdictional and modal boundaries -- the system should appear 'seamless' to the user, providing information on the entire Corridor from any point within the Corridor."
>
> Provide a foundation for the continuing, effective application of advanced technology within the Corridor as a whole."

To achieve these objectives within the context of a Corridor-wide surveillance system, standardization of surveillance data content and format seems appropriate. This standardization is necessary, for example, for information (such as incident location) collected in one jurisdiction to be shared with another jurisdiction; AVI data to be collected by multiple jurisdictions as the vehicles travel through the Corridor; and in-vehicle signing and advisory information to be provided without requiring multiple sets of onboard equipment.

Although standards must be established to support the Coalition's vision, consensus among Coalition members is necessary to properly account for the needs, interests, objectives, and constraints of individual members. With such a consensus, the Coalition would have sufficient "buying power" to create market-driven standards with the potential to become industry *de facto* standards. The establishment and adoption of standards, of course, should be based on careful analysis to avoid hindering the future implementation of emerging technologies.

Financing

While tolls are a major source of revenue for many transportation agencies in the Corridor, others depend on tax revenues (e.g., fuel, vehicle registration, etc.) to support their operations, maintenance, and improvement of their systems. These differences affect the ability of each of the member agencies to deploy and contribute to a Corridor-wide surveillance system.

In an effort to reduce the financial burden required for ITS deployment, an interest in establishing public/private partnerships has emerged. However, private sector involvement may face differing levels of acceptance across the various jurisdictions and transportation agencies. For those agencies that welcome private sector involvement, the challenge is to create enough incentive for private investment. For example, one of the principal elements of the surveillance system is the communications infrastructure, which typically represents a major capital expense. Communications companies, seeking to improve and expand their services, require the right-of-way to install cabling. By exchanging a portion of the communications capacity for the highway right-of-way, the needs of both the public and private sectors may be met.

Prior surveys have indicated a desire by member agencies to establish the Coalition as a legal entity in a manner similar to HELP, Inc. Benefits to the Coalition could be substantial because, by acting as a single entity representing a large transportation market, the Coalition could both "pool the resources" of the member agencies to facilitate a consistent level of technology deployment and attract private sector participation. In addition, the Coalition could better control the various types of transportation information to coordinate its own operation and to market the information for additional revenue.

Commercial Vehicle Regulations

The trucking industry continually confronts the problems of jurisdictional differences and institutional impediments to efficient, reliable operations. Improving the regulatory process for the trucking industry is the goal of the HELP/Crescent and Advantage I-75 Projects. These projects are deploying electronic systems which allow vehicle registration, inspection, and cargo information to be transmitted from jurisdiction to jurisdiction. This way, commercial trucks can travel across jurisdictional borders without stopping for inspection and credential verification. Such operations are also the goals of the Commercial Vehicles Operations initiative of the I-95 Corridor Coalition. Realization of these goals will result in faster and more reliable freight services, reduced vehicle operating costs, and improved economic productivity. The operational effectiveness of such a system depends on the adoption of standards for equipment, including surveillance, and the institutional arrangements within the Corridor.

Incident Management

Surveillance information has been widely used in incident detection. Incident detection techniques include:

+ Automatic algorithm analysis of point sensor data to spot potential incidents based on characteristics typical of incident conditions.

+ Incident reports from a variety of sources, such as emergency response fleets, service patrols, motorists, and media.

+ Human observation through Closed-Circuit Television (CCTV) systems for both incident detection and confirmation.

Automatic incident detection algorithms require system integration and calibration. Incident reporting depends on efforts to enhance institutional relationships with the media and emergency response agencies, as well as on motorist public relations to promote cellular call-ins to the operating agency or media. Options for CCTV coverage vary from the conventional pole-mounted detail coverage, to building mounted overview cameras and aerial coverage from aircraft.

Prior survey results from Coalition member agencies have indicated that effective corridor-wide incident management depends on each receiving "compatible" information of consistent detail and format. Consistent information is essential to manage incidents impacting neighboring jurisdictions. In such cases, incident detection and verification information should be made available to all affected agencies. Furthermore, accurate incident verification and assessment information, along with established procedures and guidelines for inter-agency coordinated responses, are essential to manage severe incidents requiring resources from multiple jurisdictions.

Since incident management effectiveness is measured in terms of both life preservation and minimization of traffic congestion, the ability to quickly dispatch the required emergency-response resources (police, towing vehicles, ambulance services, fire and rescue vehicles, or a combination thereof) to the scene is crucial. The speed of such responses, in turn, depend on the ability of the surveillance system to supply information necessary for route guidance to help emergency vehicles avoid congestion as they make their way to the scene. Because these operational issues are among those of the I-95 Corridor Coalition Projects 1 (Information Exchange Network) and 2 (Incident Management), the identified Corridor-wide surveillance system goals and objectives must be consistent with those of these projects.

2.1.3 Federal Legislative Context

ISTEA Management Systems Requirements

Volume 58, No. 229 of the *Federal Register*, dated Wednesday, December 1, 1993 contained the following summary of Intermodal Surface Transportation Efficiency Act (ISTEA) Management Systems requirements:

> " Section 1034 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) required the Secretary of Transportation to issue regulations for State development, establishment, and implementation of systems for managing highway pavement, bridges, highway safety, congestion, public transportation systems, and intermodal transportation systems."

In addition, ISTEA mandated "the development and implementation of a traffic monitoring system for highways and public transportation systems." The objective of this legislation is to " improve the efficiency and safety of, and protect the investment in, the nation' s transportation infrastructure."

The particular objectives of each of the management systems were defined in the regulation issued by the U.S. Department of Transportation' s Federal Highway Administration and Federal Transit Administration, Section 500.103 of the regulation provides a general definition of "management system" which highlights the need for an effective surveillance system. That definition states:

> " A *management system* means a systematic process, designed to assist decision makers in selecting cost effective strategies/actions to improve the efficiency and safety of, and protect the investment in, the nation's transportation infrastructure. A management system includes: identification of performance measures; data collection and analysis; determination of needs; evaluation and selection of

appropriate strategies/actions to address the needs; and evaluation of the effectiveness of the implemented strategies/actions."

In this definition, data collection and analysis and evaluation of the effectiveness of the implemented strategies/actions require high-quality surveillance data to provide an accurate assessment of conditions and the changes in conditions associated with the implementation of " strategies."

The regulations require all States with federal aid highways to develop, establish, and implement the management systems, tailored to meet State, regional, or local goals, policies, and resources. The regulations also require the States to ensure that adequate resources are available for implementation of the management systems by the target dates, and to develop databases with common or coordinated reference systems and methods for data sharing. Furthermore, the establishment, development, and implementation of the Congestion Management System, Public Transportation Facilities and Equipment Management System and Intermodal Facilities and Systems Management System, " must be coordinated among the States and MPOs to ensure compatibility of the systems and their results."

All of these regulations emphasize the need to develop a coordinated means of gathering information about the transportation system operation as a whole - in effect, a comprehensive, seamless, Corridor-wide surveillance system which will provide the foundation for improved mobility, safety, and environmental quality. The regulations are, in fact, directly met by the mission of the Coalition to " work cooperatively to improve mobility, safety, environmental quality and efficiency of inter-regional travel in the Northeast through real-time communication and operational management of the transportation system."

ISTEA Automated Highway System Mandate

The ISTEA legislation also included a mandate to demonstrate fully automated operation of a highway by 1997 with a long-range goal of deploying an Automated Highway System (AHS) in priority corridors throughout the United States. Although different AHS architectures and concepts are still under development, all will require extensive surveillance systems to ensure AHS operational safety. Surveillance system requirements of the future AHS are likely drive the evolution of surveillance technology. To ensure the Corridor-wide surveillance system compatibility with and potential migration to an automated highway system, the Coalition must stay abreast of development in this arena.

Clean Air Act

Many elements of the ISTEA legislation originated in the Clean Air Act of 1990. The Clean Air Act dictated that the level of automobile emissions be reduced to improve air quality. This broad goal can be achieved through the following two main objectives:

+ A reduction in the emission level of individual automobiles.
+ An increase in transportation system efficiency.

The first objective has little relevance to this project at this stage, although it is possible to foresee that vehicles (especially commercial vehicles) would have onboard emission monitoring systems to provide real-time vehicle emission status to roadside automated inspection stations. In fact, automated vehicle monitoring of this type is included in the list of IVHS User Services considered under the federally-funded ITS Early Deployment studies.

To increase transportation system efficiency, a number of strategies may be employed:

+ Encourage a shift from single-occupancy vehicles to high-occupancy vehicles.
+ Implement the ISTEA Management Systems.
+ Implement transportation demand management measures to alter the travel patterns to reduce peak-period congestion.

All of these strategies require a comprehensive data collection and dissemination system, both to facilitate the operational aspects of these strategies and to monitor the subsequent effects on the transportation system. Therefore, real-time surveillance of highway performance and congestion, transit performance, and other related factors is required. In addition, air quality monitoring is required to ensure compliance with the provisions of the Act.

2.1.4 Functional and Technology Context

The function of a traffic surveillance system is to acquire traffic, travel, and environmental information in an effective and timely manner to support safe and efficient movements of people and goods. Its purpose is to provide the information necessary to:

+ Optimize traffic flow through a roadway system.
+ Decrease the response time and duration of traffic incidents.
+ Help travelers to make informed decisions on mode, route, or departure time, either before or during their trips.
+ Manage traffic demand and travel patterns to improve air quality.

To fulfill the above purpose, a surveillance system must sense, process, and communicate the characteristics of the travel environment (see Figure 2-2). The order of occurrence of the latter two functions depends on the sensing technology used and the system architecture.

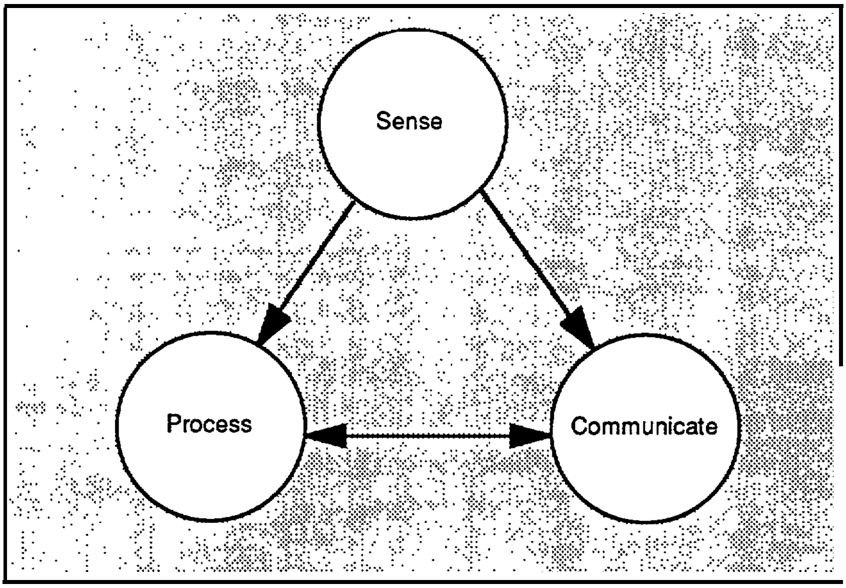

Figure 2-2. Three Primary Functions of a Surveillance System

Various surveillance technologies and techniques may be used in a Corridor-wide surveillance system (see Figure 2-3). These technologies and techniques encompass a wide spectrum of existing and emerging technologies, including defense conversion. The choice of technologies and techniques is driven by the needs, system cost and performance, and maintenance capability of participating agencies in the Corridor.

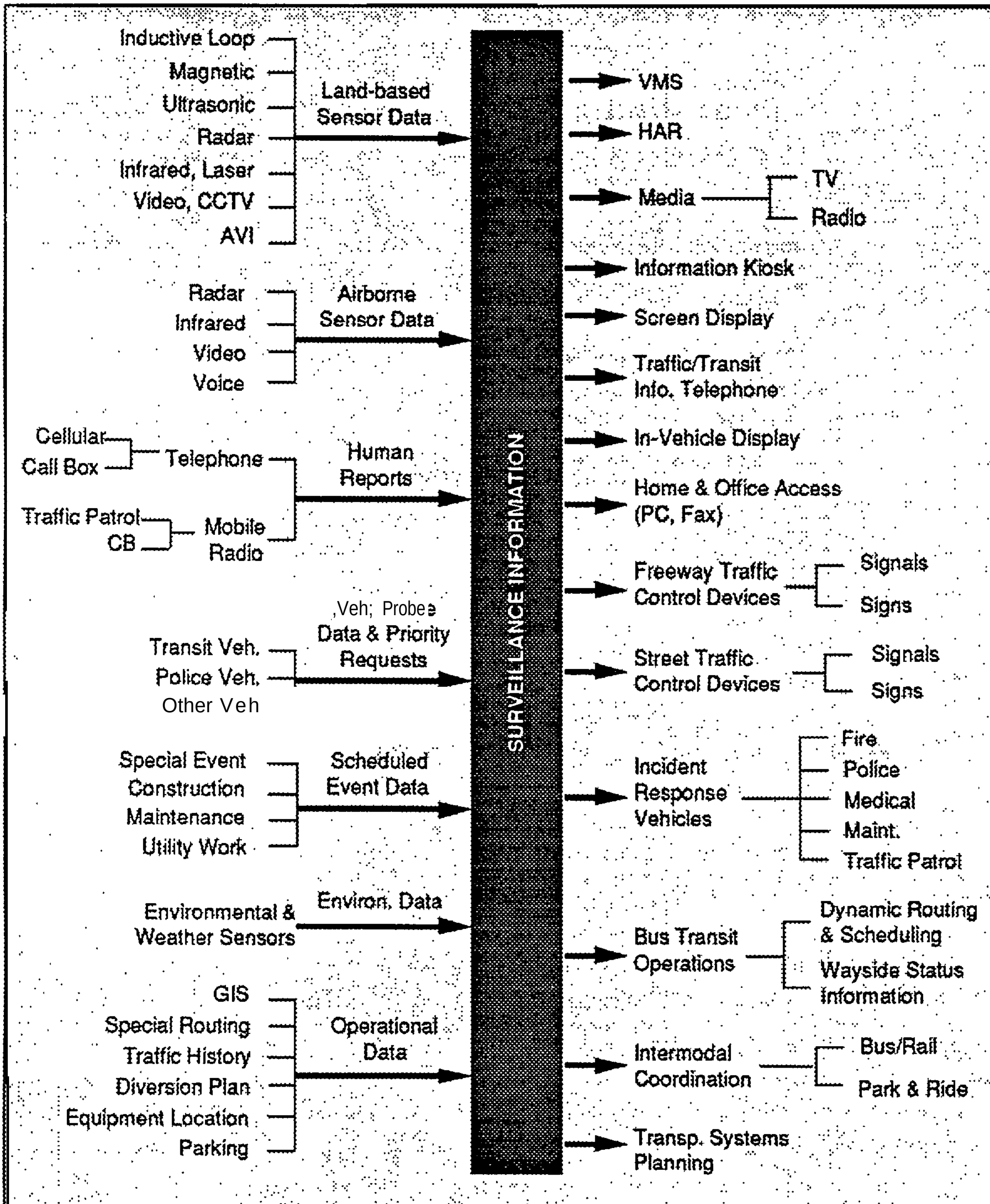

Figure 2-3. Conceptual Framework of a Surveillance System

To be cost-effective, surveillance technologies and techniques should be selected to:

+ Serve the local jurisdictions first. The Collected information may be further processed or synthesized to use at the Corridor level. For example, use mainline traffic flow data collected for ramp metering as inputs to the Corridor-wide surveillance database.

+ Synthesize information already available from other agencies to minimize investment cost. This information might include the vehicle tracking information provided by AVL systems operated by public transit agencies or fleet management operators.

+ Establish interfaces that allow road users to report traffic conditions, for example, by cellular telephone.

+ Investigate emerging and defense-conversion technologies that do not require substantial investment in the transportation and communication infrastructure. Airborne surveillance is one such technology.

These considerations are fundamental to the technology assessment and system conceptual design to be performed for this Project.

2.2 GOAL AND OBJECTIVE IDENTIFICATION: QUESTIONNAIRE SURVEY

The premise of the study, and the creation of the surveillance system goal and objective survey are to ensure that the following goals of the I-95 Corridor Coalition are met:

+ Effective management of traffic incidents and recurrent congestion to improve mobility and air quality.

+ Cooperative development and operation of an inter-regional traffic and travel communication network.

+ Transformation of the I-95 Corridor into a showcase of ITS technologies.

+ Cooperation among transportation organizations to address issues of information gathering and sharing, joint procurement, joint funding, and other areas of mutual interest.

+ Successful demonstration of the benefits of ITS and a partnership approach to addressing inter- and intra-regional transportation needs.

For the Corridor-wide surveillance system to be correctly conceived, designed, and developed, the needs and vision of Coalition members regarding the system must be understood. A survey is the best method to achieve this purpose.In this section, the approach to developing the survey and a summary of the survey results are presented.

2.2.1 Survey Design

2.2.1.1 Target Audience

The target audience for the survey includes both public and private sectors in the Corridor. Since the majority, if not all, of the public agencies are represented on the I-95 Corridor Coalition Steering Committee, the members of this Committee served as points-of-contact for the survey. In addition, the Montgomery County Department of Transportation in Maryland was selected to represent a local transportation agency. This selection was based on their many on-going ITS initiatives relevant to the Corridor-wide surveillance system. The points-of-contact for public agencies are provided in Appendix A of this report.

The original target population did not seem to have sufficient representation of transit agencies. Thus, to reflect transit agencies' view in the survey, three transit properties were invited to participate. All three accepted the invitation and provided their responses. Also to gather views from other disciplines, 2 airport authorities, and 1 private agency were included in this survey.

Separate questionnaire was developed for the private sector survey. A number of private organizations were included in the private sector survey. Three categories of potential private partners were identified: commercial traffic reporters, infrastructure providers, and fleet operators and managers (refer to Table 2-1). The points-of-contact for the private organizations are shown in Appendix B. The questionnaire that was provided to private organizations is shown in Appendix C, following the public agency questionnaire. It should be pointed out that the questionnaire to the private sector was done in conjunction with Project #8 (TIS), thus not all of the agencies listed are relevant to the SR/T project; they are being included, however, for completeness.

Table 2-1. *Potential Private Sector Companies for SR/T Partnership*

Category	Name	Function Provided
Commercial Traffic Reporters	Metro Traffic Shadow Traffic Traffax Traffic Network SmartRoute Systems Traffic Net	Traffic Surveillance and Information Dissemination
Infrastructure Providers (e.g., Communication)	Southern NE Telephone Bell Atlantic AT&T NYNEX Cellular One Sprint Time Warner Cable Telecommunications, Inc. (TCI) Continental Cable Metropolitan Fiber Systems	Communication for motorist call-ins and en route data
Fleet Operators and Managers	Federal Express UPS	Potential probe data

The survey was conducted using questionnaire and telephone interviews. The questionnaires was sent to all people on the contact list, and telephone interviews were conducted as follow-ups. The following paragraph describes the contents of the survey questionnaire.

2.2.1.2 Questionnaire Development

Since other I-95 Corridor projects were concurrently underway and already conducted their surveys with the same agencies intended for this project, the questionnaires of the related projects were reviewed to avoid duplication, thus reducing the burden on participating agencies. In particular, the questionnaires of Project #1 (IEN), Project #2 (Incident Management -- Detection, Response, and Operations), and Project #8 (TIS) were reviewed.

The Goal and Objective Questionnaire for this task includes the following four parts:

+ Goal.
+ Objective.
+ Technology.
+ Private Sector Participation.

Each part of the questionnaire contains a number of questions with multiple-choice answers. To ensure that other ideas from the respondents are captured, each section of the questionnaire has space for " other items" to be filled in by the respondents. An blank questionnaire is provided in Appendix C.

Goal Questionnaire

To seek consensus on the overall goal of the Corridor-wide surveillance system, a candidate goal was provided as follows:

> " The overall goal of the Surveillance System is to acquire and provide traffic, travel, and environmental information along major roads and at key locations in a timely and cost-effective manner to enhance the safe and efficient movements of people and goods in the Corridor."

The respondents were asked to modify this goal statement to suit their perspective of the system. For specific goals, eight candidates were identified for rating according to their perceived relative importance (low, medium, and high). The stem goals are to acquire and provide information to:

+ Enhance traffic incident management.
+ Enhance real-time traffic control operations.
+ Support traffic law and regulation enforcement.
+ Enhance traffic management during snow storms and other emergencies.

+ Facilitate Travel Demand Management strategy implementation.

+ Improve multi-modal and inter-modal transportation operations.

+ Enhance the transportation systems planning database.

+ Support Traveler Information Services.

For each specific goal, a set of associated objectives were developed for rating as described below in the Objective Questionnaire.

Objective Questionnaire

The purpose of the objective questionnaire is to identify and prioritize objectives supporting the associated goal. The respondents were asked to rate each candidate objective as shown in Table 2-2.

Technology Questionnaire

This questionnaire addresses two issues: the vision of the Coalition members on the types of surveillance technologies to be used in the short term (within 5 years) and the long term (5 to 20 years): and the types of vehicle detection technologies that the Coalition members are likely to use in the future.In an effort to provide a uniform understanding of the various surveillance technologies, a short paper on surveillance system background was provided in the questionnaire package (see Appendix D).

The types of surveillance technologies and techniques contained in this questionnaire are summarized in Table 2-3.

Private Sector Participation Questionnaire

To obtain the view of the public sector on the public/private partnership, public agencies were asked three specific items:

Table 2-2. Candidate Objectives for the Corridor-wide Surveillance System

Candidate Goals	Candidate Objectives
1 Enhance traffic incident management	- Provide data for automated traffic incident detection - Detect disabled vehicles and assistance requests - Verify traffic incident reports - Assess the severity of traffic incidents - Provide information for coordinated incident responses - Provide continuous tracking of hazardous material (HAZMAT) carriers
2. Enhance real-time traffic control operations	- Improve ramp metering - Support real-time, traffic adaptive control - Facilitate reversible-lane operations - Enhance (HOV) control and operations - Accommodate priority vehicles (at signalized intersections and railroad crossings) - Accommodate variable speed limit determination - Support congestion pricing
3. Support traffic law and regulation enforcement	- Provide speed measurements - Provide weight measurements - Provide vehicle height and width measurements - Determine vehicle occupancy (for HOV)
4. Enhance traffic management during snow storms and other emergencies	- Support adaptive control (adverse weather and emergency conditions) - Support snow removal scheduling and operations
5. Facilitate Travel Demand Management strategy implementation	- Identify traffic congestion locations and levels - Characterize traffic demand levels (e.g., V/C versus time of day) - Monitor air quality
6. Improve multi-modal and inter-modal transportation operations	- Track transit vehicle location and schedule adherence - Provide transit vehicle tracks as probe data - Provide link travel times for transit time of arrival estimates - Provide passenger loading estimates - Provide park-and-ride lot status - Provide traveler security surveillance at transit stops and stations
7. Enhance the transportation systems planning database	- Provide traffic count data - Provide VMT data - Provide traffic composition data - Provide delay data - Provide vehicle O-D data - Provide incident data (location, type, severity, time-of-day)
8. Support TIS	- Provide traffic conditions information (e.g.. congestion, incident) - Provide roadway conditions information (e.g.. closure, snow/ice) - Provide parking information (e.g., park-and-ride, at destination) - Provide urban transit information (e.g., times of arrival/departure and operational status) - Provide inter-urban transit information (e.g.. times of arrival/departure and operational status)

+ Whether or not the agency favors of public/private partnerships in a Corridor-wide surveillance system. Their position on this matter helps to define the role of the private sector.

Table 2-3. Surveillance Technologies and Techniques Considered in Survey

Surveillance Technologies and Techniques	**Vehicle Detection Technologies**
Vehicle Detectors	Inductive loop
Weigh-in-Motion (WIM) sensors	Magnetic
Video image (CCTV) system	Magnetometer
Automated Vehicle Location (AVL)	Pressure
Automated Vehicle Identification (AVI)	Sonic and Ultrasonic
Aerial Surveillance	Infrared
Environmental Sensors:	Light-emission photo-electric
Pavement surface condition (dry/wet/icy)	Microwave/radar
Fog/visibility	Video image processing
Wind speed/direction	
Air quality	
Human Surveillance:	
Police Patrol	
Motorist Call-In	
Freeway Service Patrol	
Commercial Traffic Reports	

+ Whether or not the agency has an existing public/private partnership. From these existing relationships, the types of information shared and the direction of information flow were asked to be described.Four candidate types of information were included:

  - Incident and congestion reports.
  - Roadway conditions.
  - Weather and visibility.
  - Traffic advisory.

+ The challenges and issues that the agency perceives in such relationships. A list of possible issues and challenges was provided for rating, along with a request to identify other challenges and issues. This list includes:

  - Ownership of information.
  - Sharing of right-of-way for surveillance infrastructure.
  - Funding arrangement.

- Liability.
- Ability to maintain a long term partnership.
- Partner responsiveness.
- Competition among private organizations.

A similar, yet more detailed, type of request was included in the private sector survey of Project #8 (TIS).

2.2.2 Analysis Of Survey Results

The Task 1 Goal and Objective Questionnaires were sent to 37 Coalition member agencies, and 3 selected transit agencies, 2 airport authorities and one private agency.Transit agencies included Southeastern Pennsylvania Transit (SEPTA), NJ Transit and MD Mass Transit. The two airport authorities are Baltimore-Washington International and Philadelphia international. The additional private agency surveyed is SmartRoute System. Altogether there were a total of 34 respondents. Reference Table 2-4 for a count of respondents by transportation agency or organization.

Table 2-4. List of Respondents

Category	Number of Respondents	Number Surveyed	Percentage Complete
State Departments of Transportation	11	14	79%
Transportation Authorities	10	12	83%
Affiliated Organizations	7	11	64%
Transit Agencies	3	3	100%
Airport Authorities	2	2	100%
Private Agency	1	1	100%
Total	*34*	*43*	*79%*

Since this questionnaire was distributed to various public and private agencies (reference Appendices A and B), data will, in a few cases, be reported by type of transportation agency (e.g., DOT, Authority, Other Affiliated, or Transit Agencies). For reporting purposes transit and modal agencies (e.g., Amtrak and the U.S. Office of Intermodalism) are reported together.

Graphic profiles, presented in Figures 2-4 through 2-43, display raw data results and ranks, respectively. Ranks were developed by accumulating and averaging on a scale of 4, the responses associated with each of the questions.Results from each of the following four questionnaire categories will be reported:

1. Goal.
2. Objective.
3. Technology.
4. Private Sector Participation.

2.2.2.1 Goal Survey Results

The overall goal was modified based on the survey responses. There were suggestions to replace the word "traffic" with "transportation" in the strawman goal so that it covers all modes of transportation. The modified goal is as follows:

> "The overall goal of the Surveillance System is to acquire and provide transportation, travel, and environmental information along major roads and at key locations in a timely and cost-effective manner to enhance the safe and efficient movements of people and goods in the Corridor."

The overall responses related to the goals indicated that none of the eight goals were rejected in the survey although individual scores for the goals varied. Therefore, it appears that all the goals were reasonable to the surveyed audience.

Figures 2-4 and 2-5 are graphic profiles of data obtained from all respondents. Both graphics support the following conclusions:

+ The single most important goal with the highest priority, revealed by over 88% of respondents, is the need to enhance traffic incident management.

+ The second position had a tie with two objectives - supporting real-time traffic control operations, and enhancing traffic management during snow storms.

  A total of 74% respondents rated supporting real-time traffic control operations as high. These results are consistent with the findings developed by Project #17 [Howard/Stein-Hudson, October 1994] and a vast number of other findings for state projects.

  Approximately 68% of respondents marked enhancing traffic management during snow storms and other emergencies as high.

+ The use of surveillance data to support traffic law and regulation enforcement was the least important goal to respondents. Only 18% of respondents viewed this as high.

An additional goal, noted by one respondent, was to " monitor and determine environmental impacts" . Although not specifically called out as a goal, " monitor air quality" is an objective for the goal of Enhancing TDM strategy implementation.

Figure 2-6, provides a prioritized comparison of SR/T goals among responding groups. From the graphic, the following inferences can be made:

+ Although all groups responded with relatively high priority, enhancing real-time traffic control operations is more important to transit agencies than DOTs and Authorities.

+ As expected, improving multi-modal and inter-modal transportation is more important to transit agencies than DOTs or Transportation Authorities.

+ Again, although all groups responded with relatively high priority, supporting traveler information services is more important to transit agencies than DOTs and Authorities.

+ Enhancing transportation systems planning databases is more important to transit agencies than DOTs.

+ Although supporting traffic law and regulation enforcement is relatively low in priority when compared with other goals, Transportation Authorities rank it considerably higher than transit agencies and DOTs.

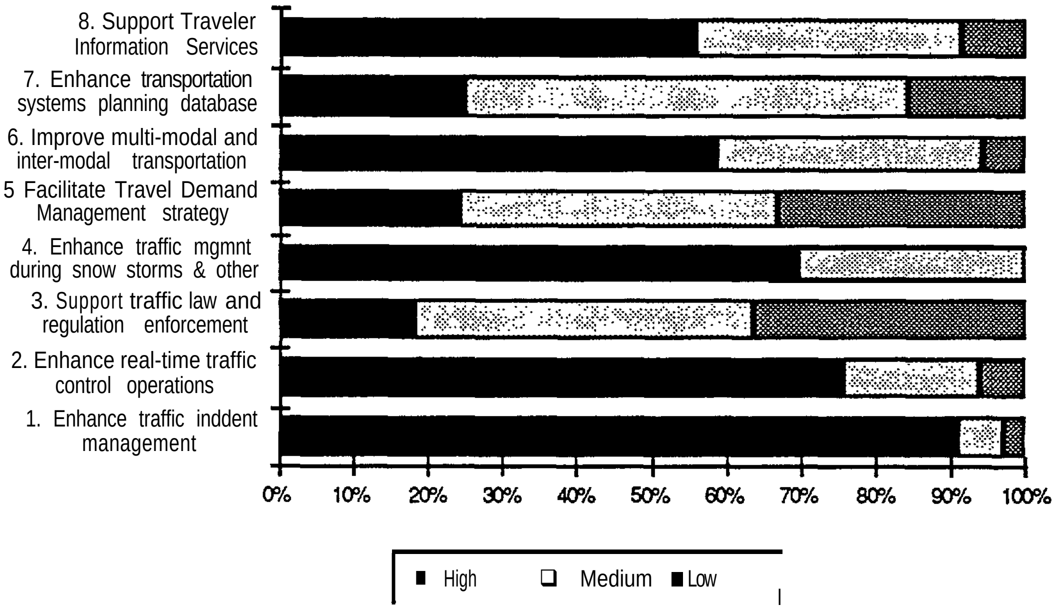

Figure 2-4. SR/T Goals - Distribution of Responses from All Agencies

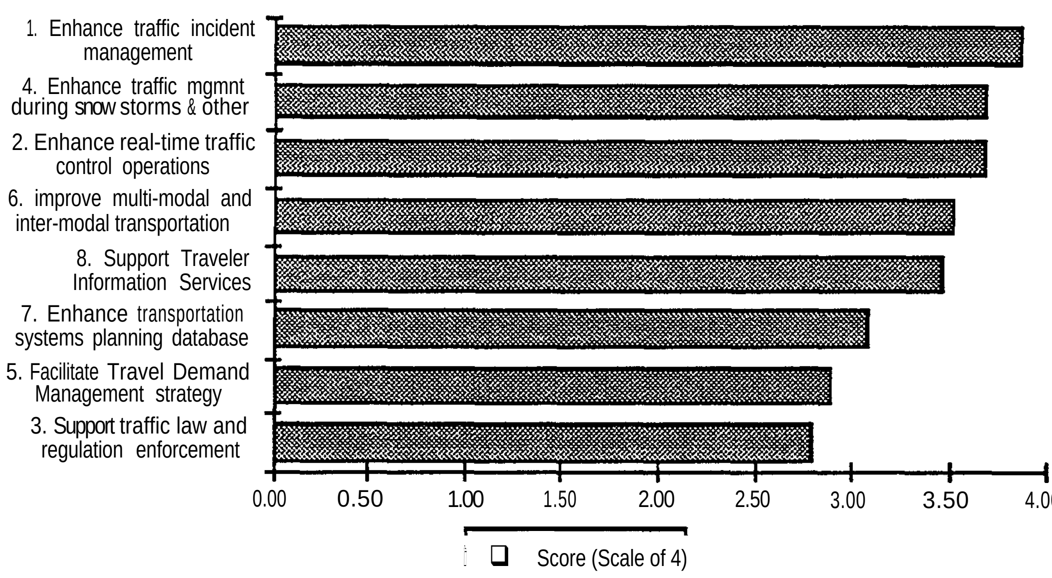

Figure 2-5. SR/T Goals - Ranking Derived from All Responses

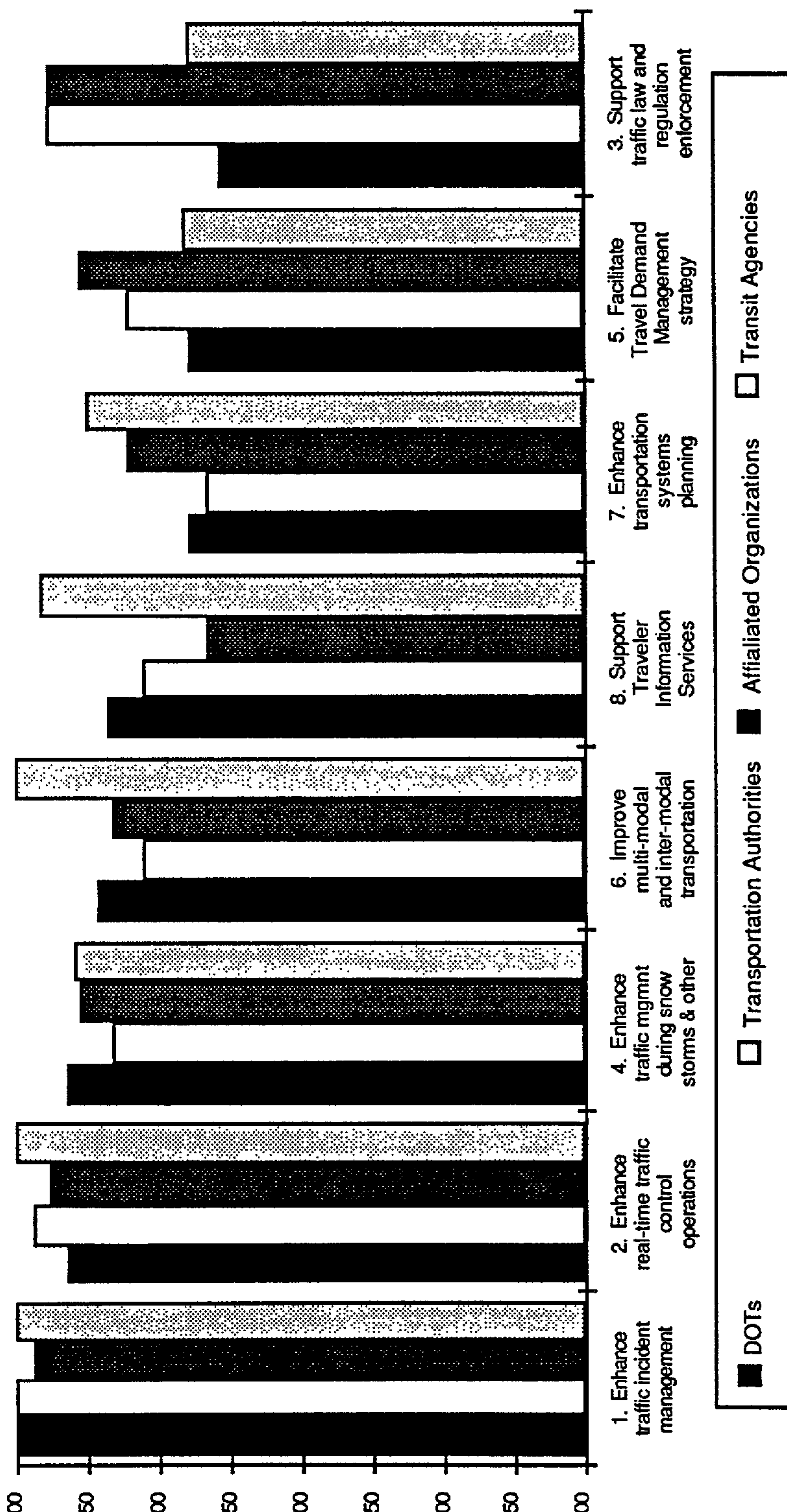

Figure 2-6. SR/T Goals - A Comparison of Goal Ratings by Responding Agencies

Figures 2-7 through 2-14 describe raw and ranked summary results for each of the four groups: DOTs; Transportation Authorities; Affiliated Organizations: and Transit Agencies. This information is being supplied to further understand the segmentation of information.

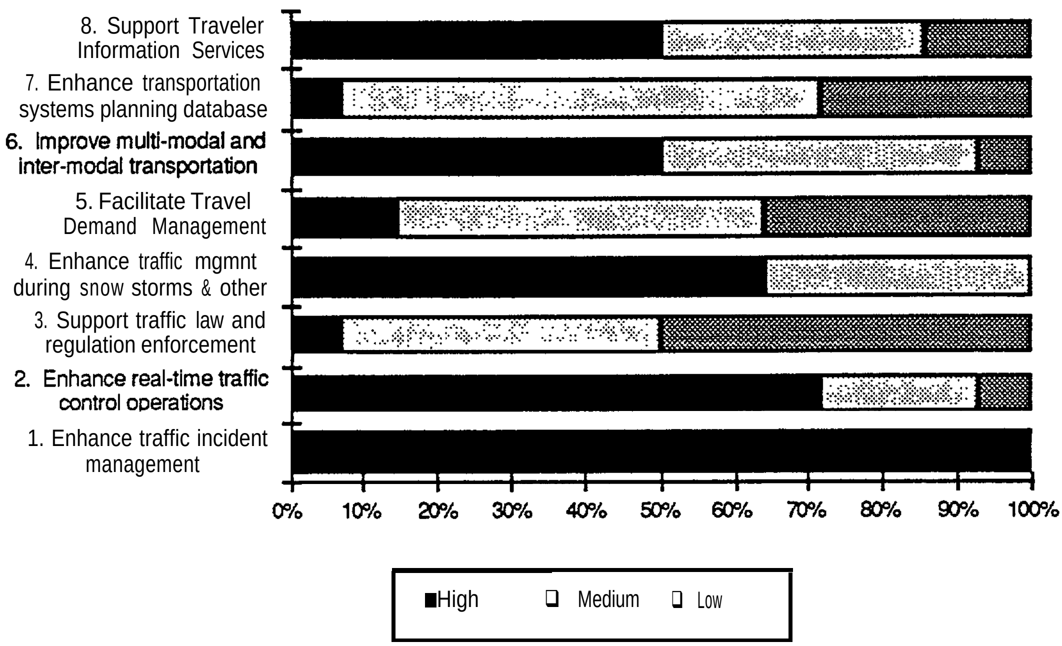

Figure 2-7. SR/T Goals - Distribution of Responses from State DOTs

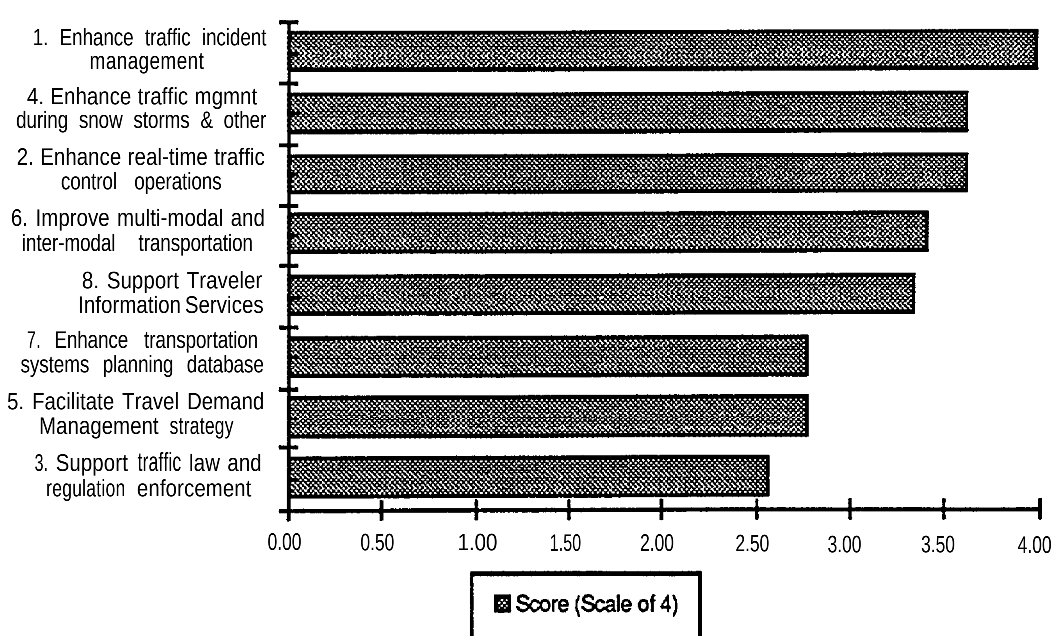

Figure 2-8. SR/T Goals - Ranking Derived from State DOTs' Responses

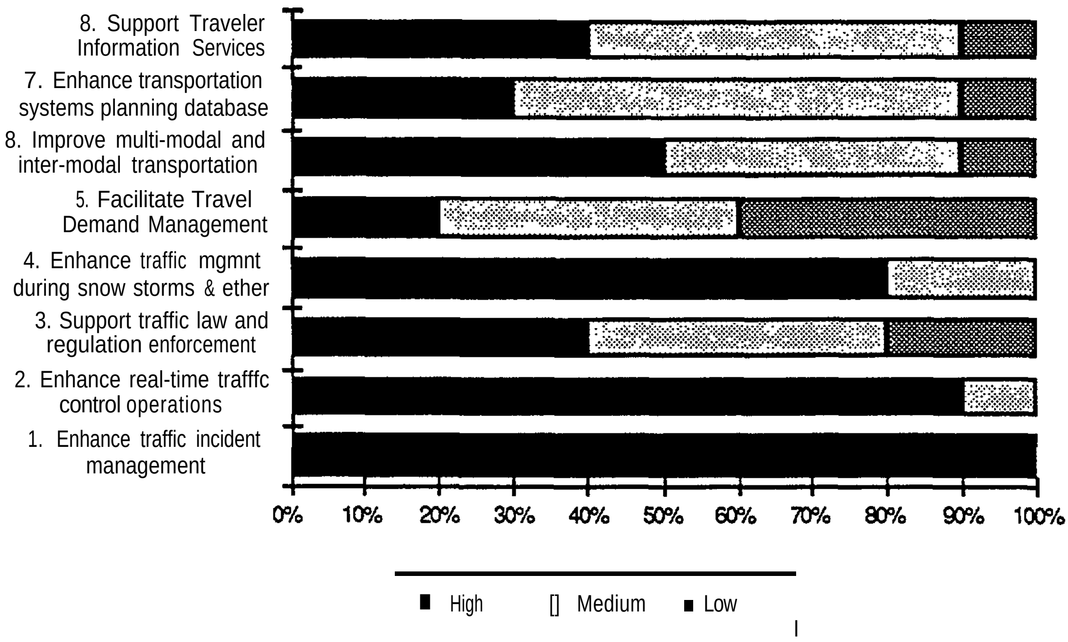

Figure 2-9. SR/T Goals - Distribution of Responses from Transportation Authorities

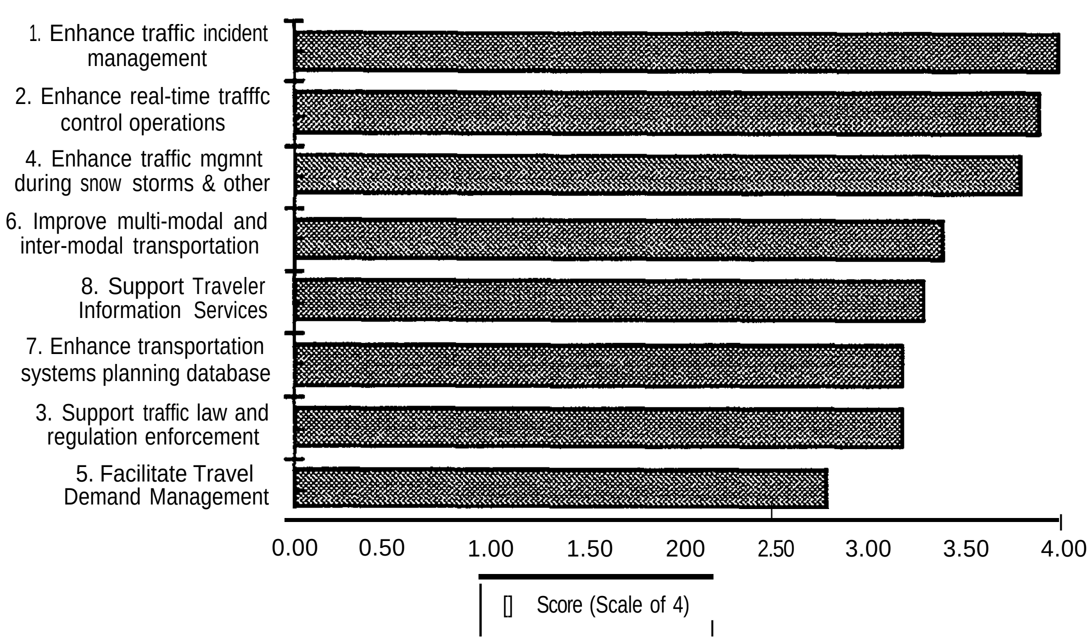

Figure 2-10. SR/T Goals - Ranking Derived from Transportation Authorities Responses*

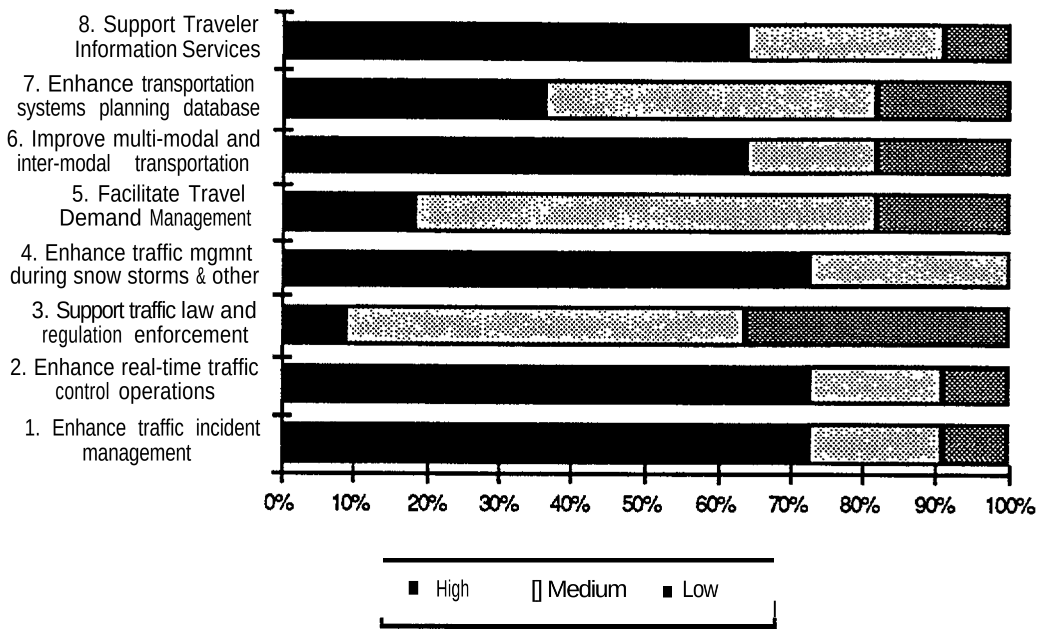

Figure 2-11. SR/T Goals -Distribution of Responses from Affiliated Public and Private Organizations

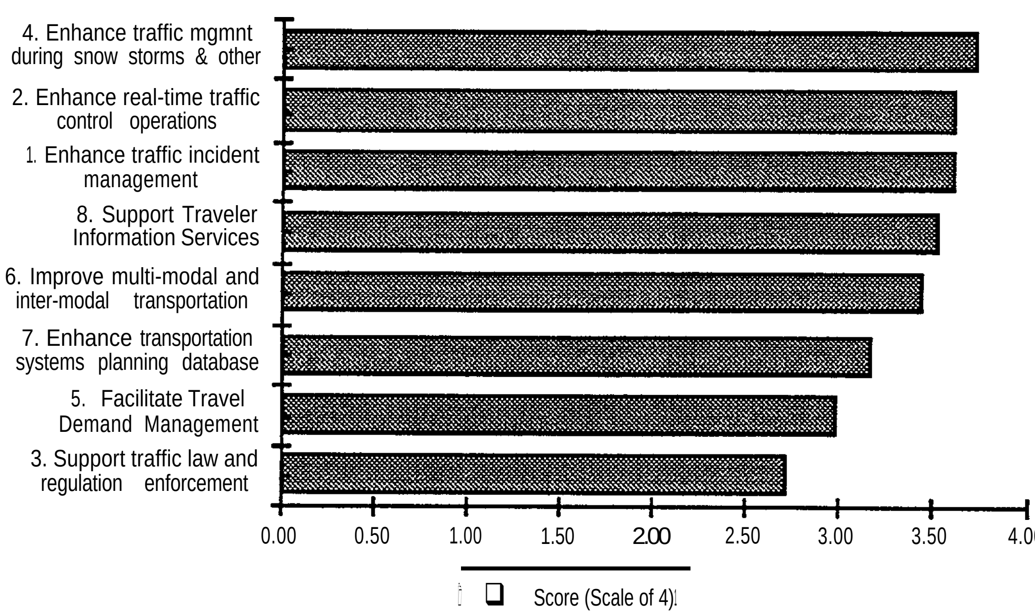

Figure 2-12. SR/T Goals - Ranking Derived from Affiliated Public and Private Organizations' Responses

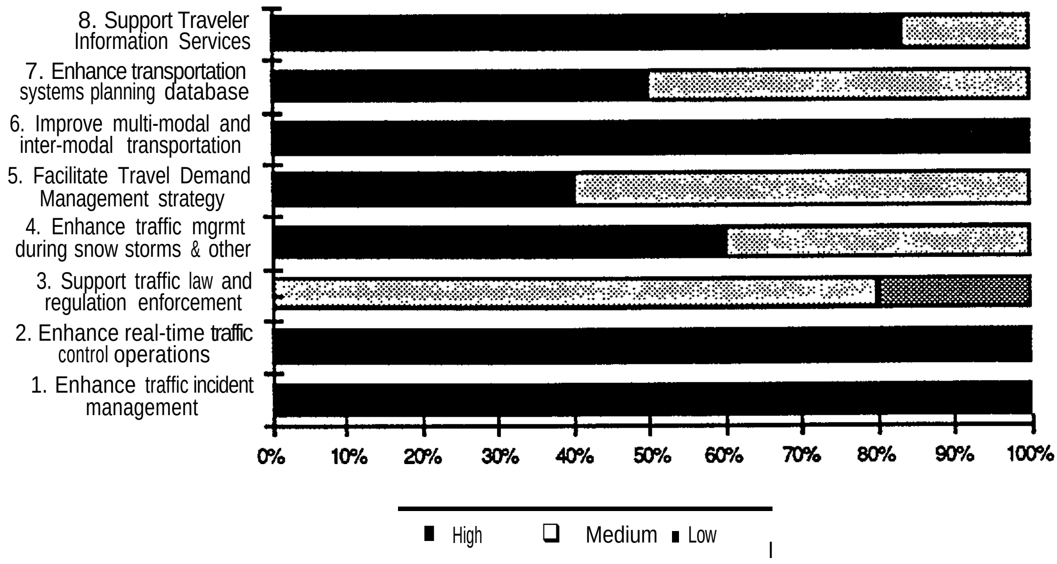

Figure 2-13. SR/T Goals - Distribution of Responses from Transit Agencies

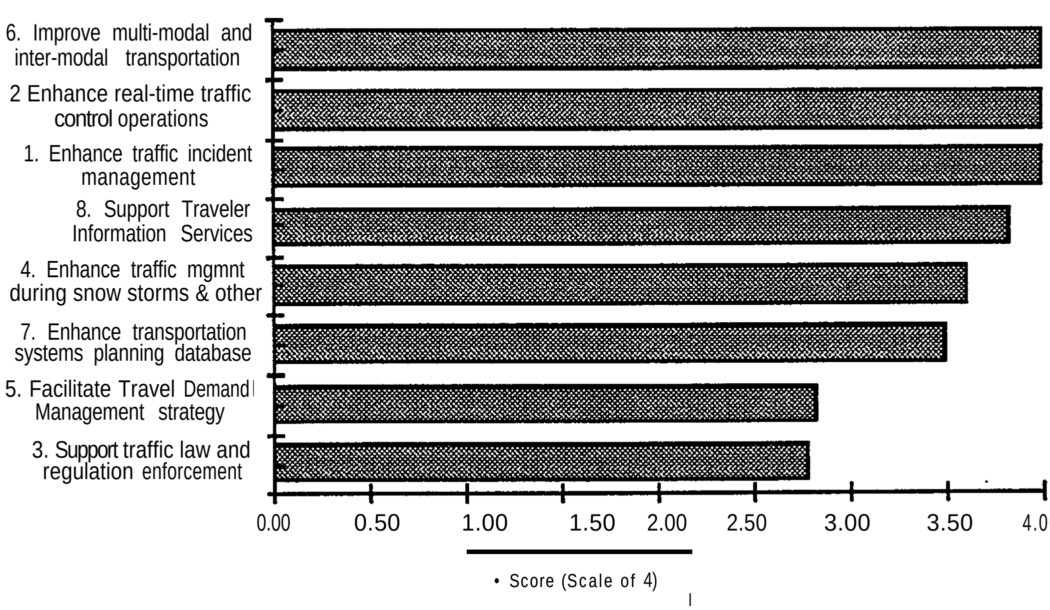

Figure 2-14. SR/T Goals - Ranking Derived from Transit Agencies' Responses

2.2.2.2 Objective Survey Results

The overall responses related to the objectives indicated that none of the identified objectives were rejected in the survey although individual scores for the objectives varied. Therefore, it appears that all the objectives were reasonable to the surveyed audience. A detailed analysis of results for objectives to support each of the primary eight SR/T goals is provided in the following paragraphs.

Goal 1 - Enhance Traffic Incident Management

Figures 2-15 and 2-16 summarize the results for the objectives to enhance traffic incident management, the single most important goal to all agencies. From the graphics, the following inferences can be made:

+ As expected, providing data for automated incident detection and coordinated incident response were the two highest ranking objectives. Eighty-two percent of respondents ranked providing data for automated incident detection as high and 73% ranked providing information for coordinated incident response as high.
+ The verification of incident reports, assessing the severity of incidents, and detection of disabled vehicles and assistance requests were the next 3 highest priority objectives, respectively. All three, however, were reported with relatively similar ranking - in Figure 2-16, the distinction is very fine.
+ The lowest ranking objective was continuous tracking of HAZMAT vehicles.

An additional suggestion, from one respondent, was to provide data to travelers.

The predominant objective of providing data for automated incident detection is supported in two ways: (1) from the responses to the goals for surveillance technology (reference section 2.2.2.3); and (2) from an analysis of existing and planned sensor systems. As discussed later in Chapter 3 (System Inventory) of this Report, most jurisdictions are deploying loop detectors, CCTV, and radar sensors to meet incident detection needs. CCTV in particular, has raised expectation levels and optimism, with respect to verifying incidents, detecting disabled vehicles, and assessing incident severity. This is expected to increase as more CCTV systems are deployed; as advances are made in machine vision; and as CCTV technology improves and matures with respect to operating at night and during all weather conditions.

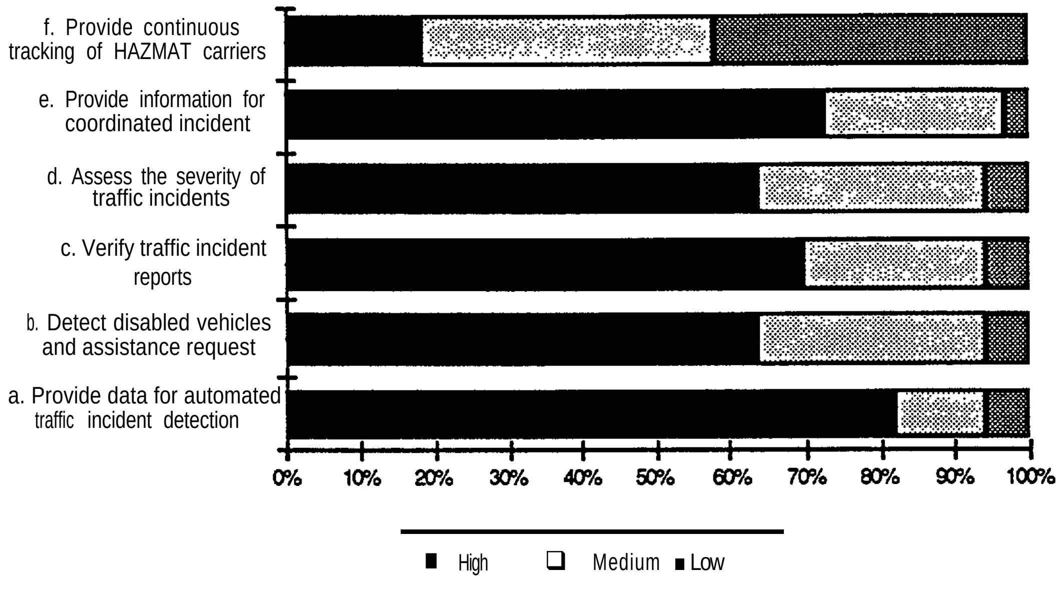

Figure 2-15. Objectives to Enhance Traffic Incident Management - Distribution of Responses from All Agencies

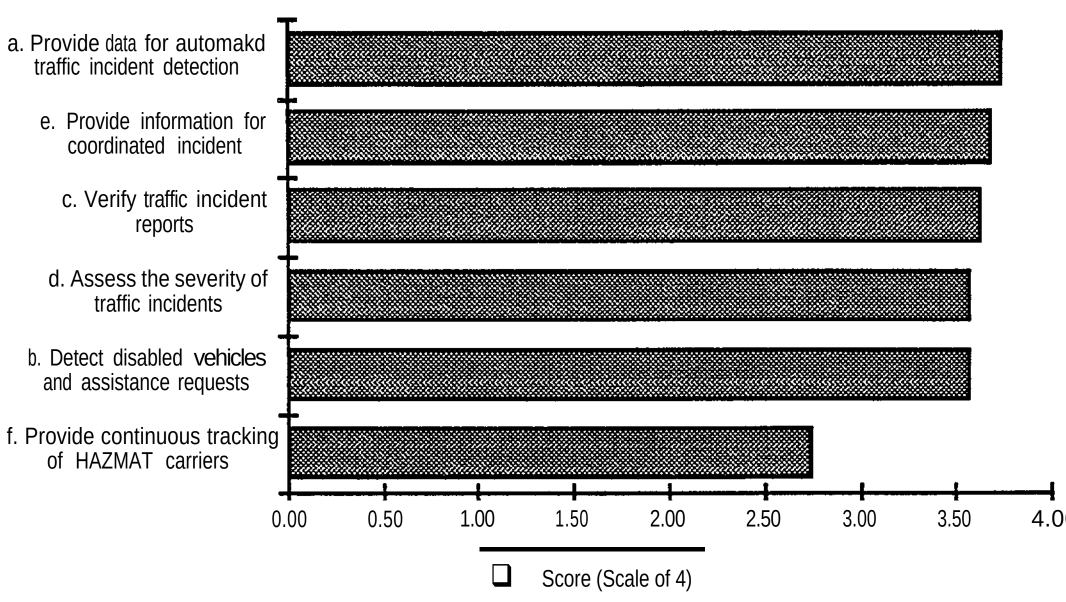

Figure 2- 16. Objectives to Enhance Traffic Incident Management - Ranking Derived from All Responses

Goal 2 · Enhanced Real-Time Traffic Control Operations

Figures 2-17 and 2-18 summarize the results for the objectives to enhance real-time traffic control operations, the second most important overall goal (tied with Goal #4). From the graphics, one can glean the following:

+ Supporting real-time, traffic adaptive control is the highest priority objective; over 50% of respondents ranked this as high.
+ Enhancing HOV control and operations, accommodating priority vehicles, and facilitating reversible-lane operations are the 3 next highest priority objectives, respectively.
+ Improving ramp metering, supporting congestion pricing, and accommodating variable speed limit determination were respectively ranked the lowest. Thirty percent of the respondents, however, associated high priority with the need to support congestion pricing.

The objective to " accommodate priority vehicles (at signalized intersections and rail-road crossing)" received a weighted average rating of 3.06 (where 3 is of a medium level of significance and 4.0 is of a high level of significance). This rating appeared to be slightly lower than the consistently high rating of objectives relating to incident management (Goal 1). This may be attributed to the fact that if a priority vehicle had been understood as an emergency-response vehicle, the rating might have been higher and, thus, consistent with the observed trend.

The low score of improving ramp metering was somewhat surprising, but can be attributed to a few reasons, including: (a) ramp metering is not widely used in the Corridor: (b) the difficulty in coordinating freeway and urban street operations; and (c) the existing road network might not be suitable to realize the maximum benefits of ramp metering.

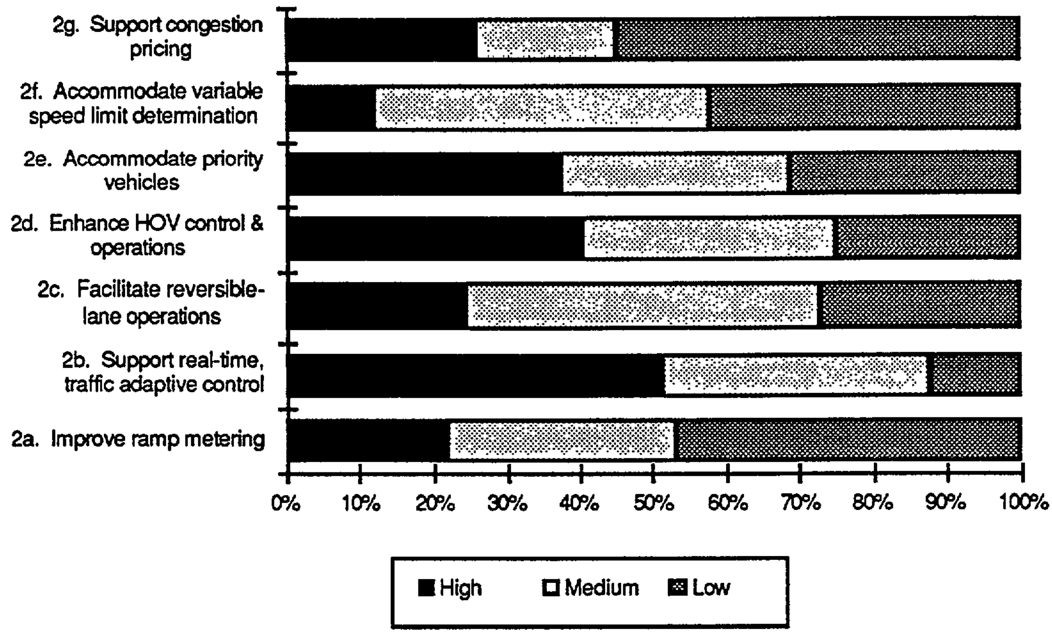

Figure 2-17. Objectives to Enhance Real-Time Traffic Control Operations - Distribution of Responses from All Agencies

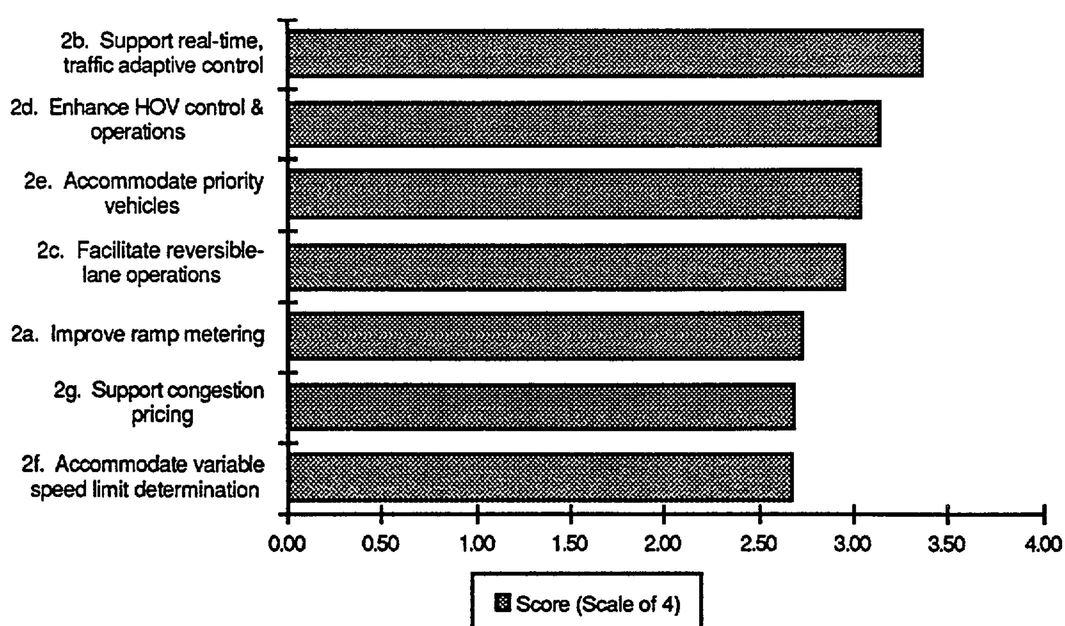

Figure 2-18. Objectives to Enhance Real-Time Traffic Control Operations - Ranking Derived from All Responses

Goal 3 Support Traffic Law and Regulation Enforcement

Figures 2-19 and 2-20 summarize the results for the objectives to support traffic law and regulation enforcement, the lowest ranked goal. From the graphics, the following conclusions can be made:

+ The objective of providing weight measurements had the most number of respondents assigning high priority (over 31%). The overall prioritization, shown in Figure 2-20, also supports the conclusion that this objective is most important with respect to law enforcement.

+ Providing vehicle height and width measurements and determining vehicle occupancy (for HOV) are the 2 next highest priority objectives, respectively. These two objectives, however, had less than 25% of the respondents rank them as high.

+ Providing speed measurements was overall the least important objective to the Coalition. As one respondent indicated, " the system [ITS] is not meant to be used that way. If it was, it would deter public support for the system."

Goal 4 - Enhance Traffic Management During Snow Storms and Other Emergencies

Figures 2-21 and 2-22 summarize the results for the objectives to enhance traffic incident management during snow storms, the second most important goal (tied with Goal #2) to all agencies. From the graphics, the following inferences can be made:

+ Supporting real-time, traffic adaptive control is the highest priority objective; 66% of respondents ranked this as high.

+ Supporting snow removal scheduling and operations is the second highest priority objective; 59% of respondents ranked this as high.

Finally, an additional goal noted by one respondent, was " to advise travelers of alternative transportation" .

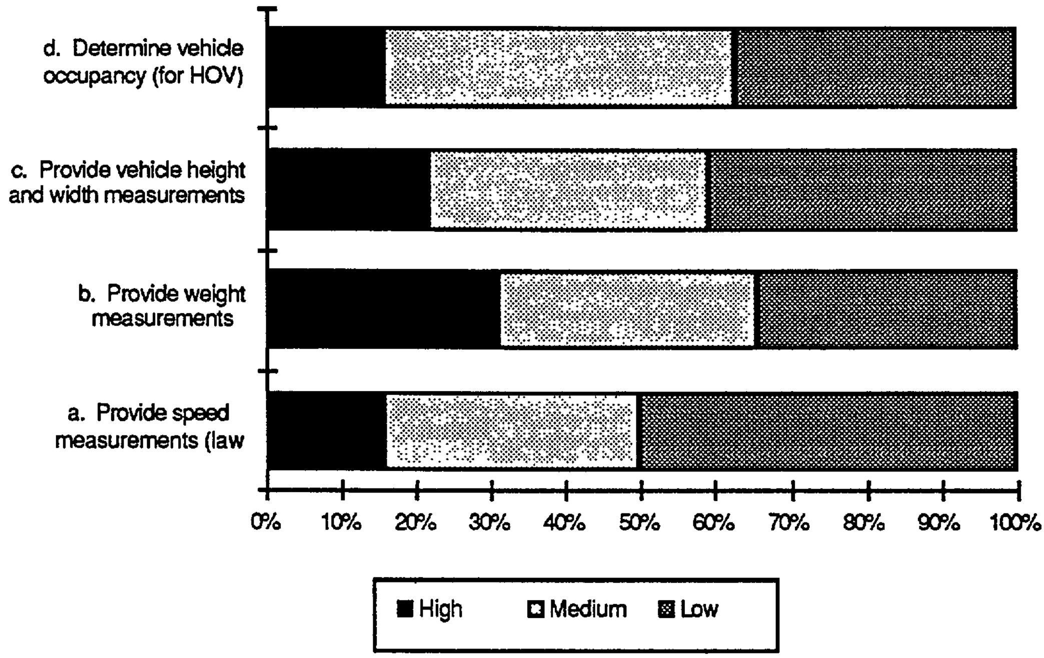

Figure 2-19. Objectives to Support Traffic Law and Regulation Enforcement - Distribution of Responses from All Agencies

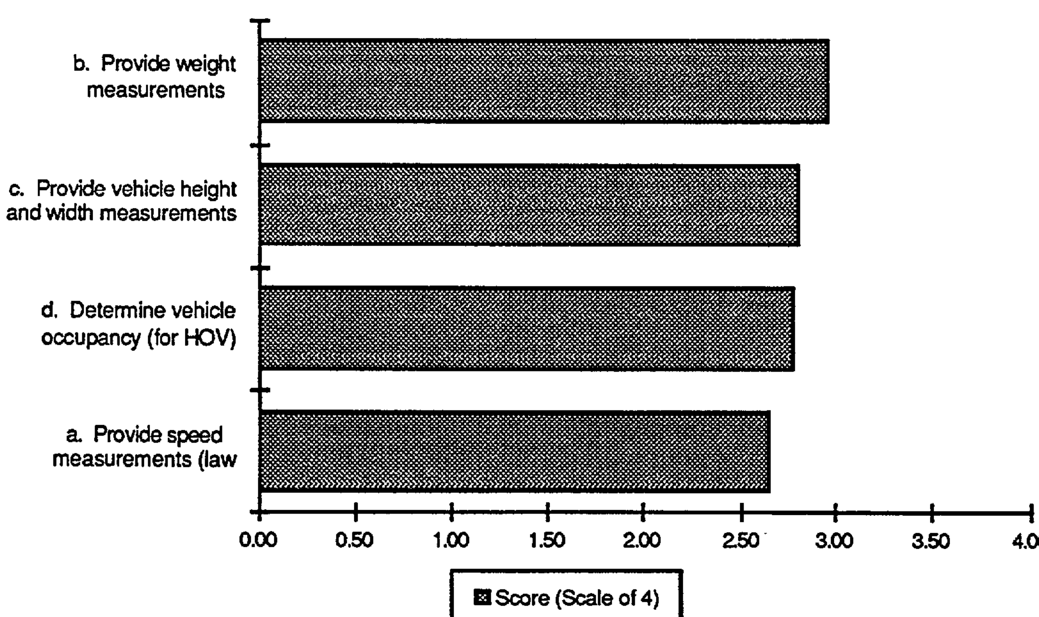

Figure 2-20. Objectives to Support Traffic Law and Regulation Enforcement - Ranking Derived from All Responses

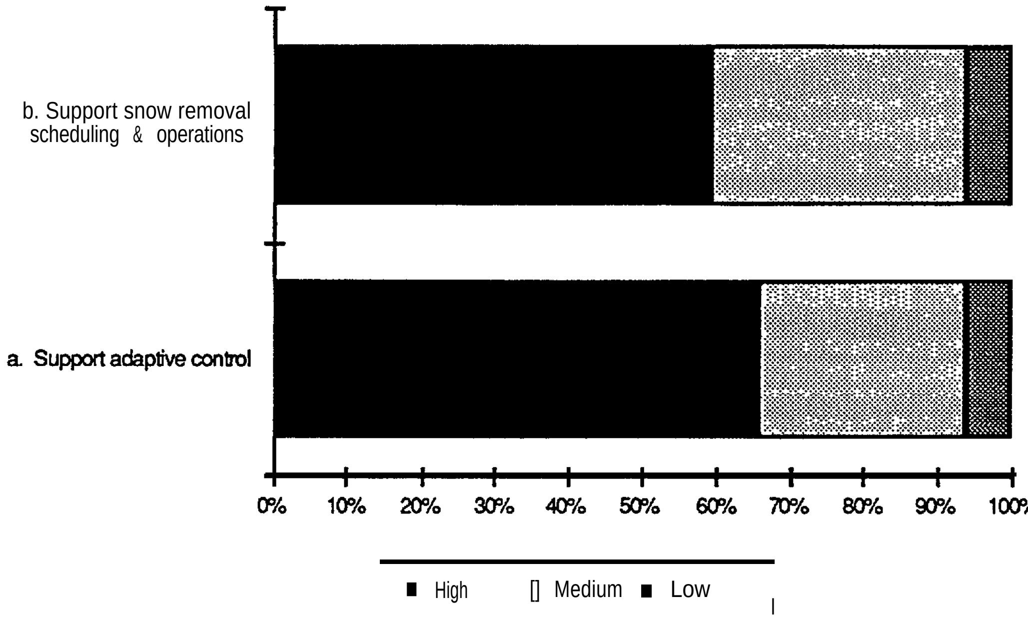

Figure 2-21. Objectives to Enhance Traffic Management During Snow Storms Distribution of Responses from All Agencies

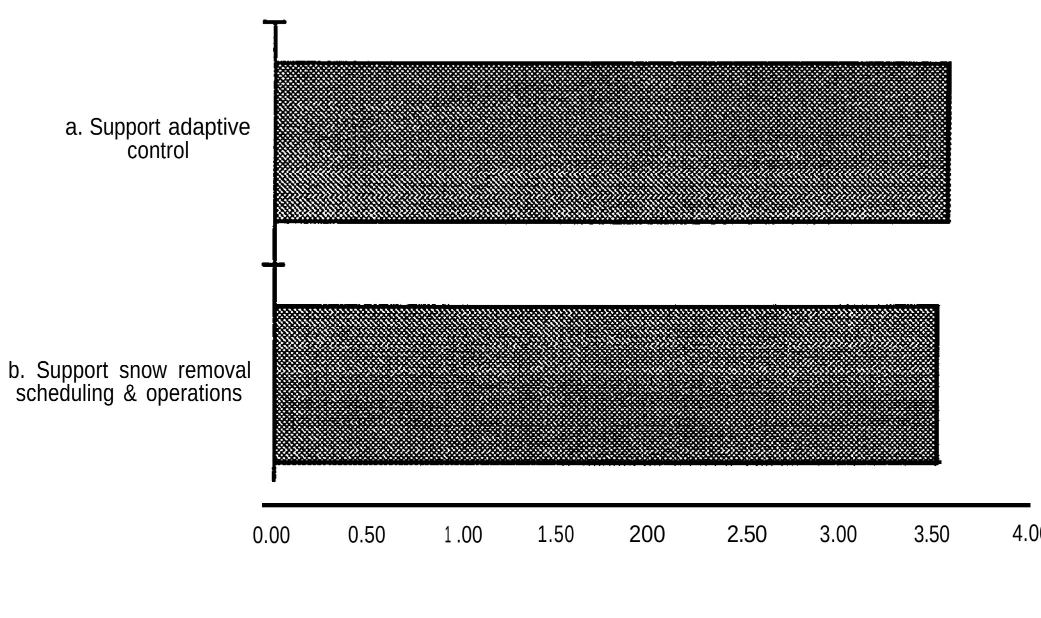

Figure 2-22. Objectives to Enhance Traffic Management During Snow Storms - Ranking Derived from All Responses

Goal 5 -Facilitate Travel Demand Management Strategy Implementation

Figures 2-23 and 2-24 summarize the results for the objectives to facilitate Travel Demand Management (TDM) strategy implementation, the second lowest ranked SR/T goal. From the graphics, the following conclusions can be made:

+ The objective of identifying traffic congestion locations and levels had the most number of respondents assigning high priority (69%). The overall ranking, shown in Figure 2-24, also supports the conclusion that this objective is most important with respect to TDM.

+ Characterizing traffic demand levels (e.g., V/C vs. time of day) was the next highest objective, receiving a high priority from 40% of the respondents.

+ Monitoring air quality was overall the lowest ranked objective to support TDM.

The objective to “monitor air quality” received a “medium significance” rating of 2.64, behind “identifying traffic congestion and levels” and “characterizing traffic demand levels.” One possible interpretation of this result is that effective implementation of TDM strategies based on traffic congestion characteristics in general is believed to result in improved air quality, which is among the primary goals of the Coalition. This interpretation is consistent with the overall survey result emphasizing the reduction of non-recurrent and recurrent congestion as top priorities. The monitoring of air quality will contribute to evaluating the effectiveness of and refining the various travel demand reduction techniques and operational management strategies.

Another possible interpretation of this survey result is that other agencies (e.g., EPA) within a state or jurisdiction are usually responsible for monitoring air quality and provide this information to transportation agencies for incorporation in their implementation of travel demand reduction techniques or operational management strategies. The interest and/or intent to monitor air quality for future operations, however, seem to grow among the agencies surveyed (discussed later in Section 2.2.2.3). Evidence of this interest is in the ratings for short-term and long-term surveillance technology vision.For the short-term vision (within 5 years), the weighted average rating for using air quality sensors was 2.64, whereas that for the long-term (beyond 5 years) was 3.13.

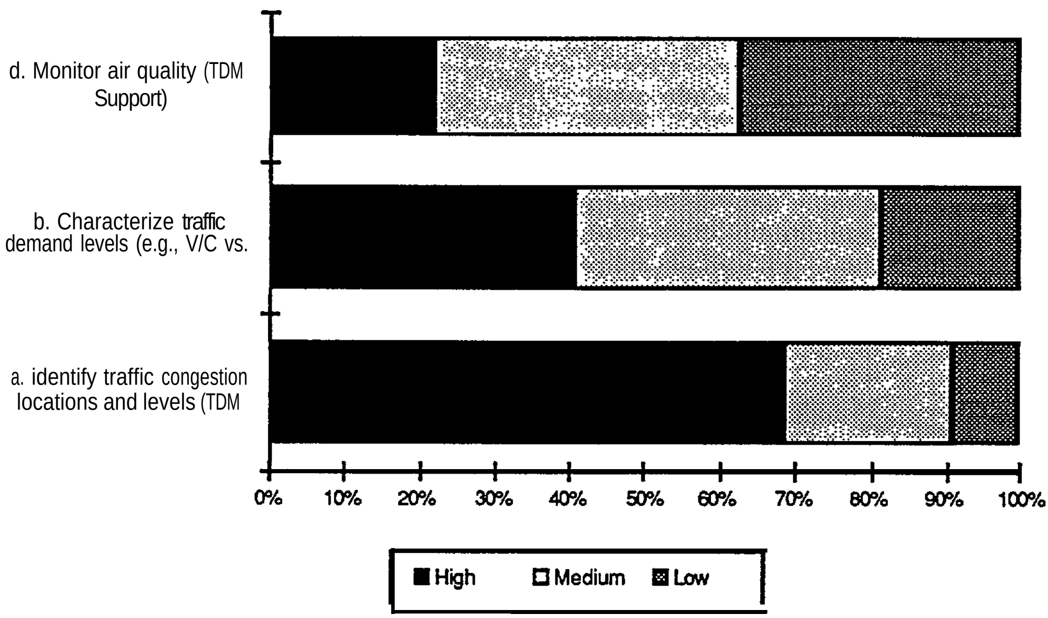

Figure 2-23. Objectives to Facilitate TDM Strategy implementation - Distribution of Responses from All Agencies

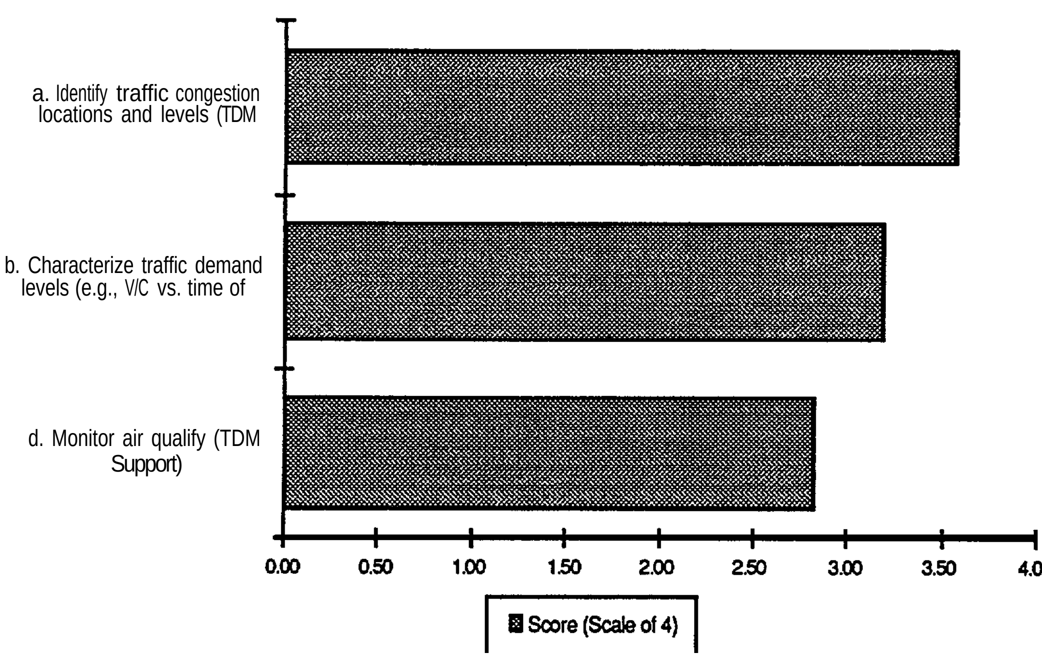

Figure 2-24. Objectives to Facilitate TDM Strategy Implementation - Ranking Derived from All Responses

The third interpretation is that the survey population was more operations oriented but this objective is more of a planning concern. If the population had included more planners, the result of this rating would have been different.

Goal 6 - Improve Multi-Modal and inter-Modal Transportation Operations

Figures 2-25 and 2-26 summarize the results for the objectives to improve multi-modal and inter-modal transportation operations, the fourth most important goal to all agencies. For analysis and reporting purposes, we had expected to present the data comparing responses from highway agencies to that of transit agencies. Because there was one-to-one correspondence on the averaged ranking, only the information gathered from all respondents will be presented. Percentages of rating, however, will be explicitly mentioned below to underscore their needs.

From the data gathered from all respondents, the following inferences can be made:

+ Providing traveler security surveillance at transit stops and stations is the most important objective: over 56% of respondents ranked this as high, and 100% of transit agencies rated this as high.

+ Providing link travel times for transit time of arrival estimates is the second most important objective.Fifty percent of respondents ranked this as high, and again 100% of transit agencies rated this as high

+ Tracking transit vehicle location and schedule adherence is the third highest overall objective; over 44% of respondents deemed this as high.

+ Providing transit vehicle tracks as probe data and providing park-and-ride lot status information were the next highest ranked objectives, respectively. Interestingly only 38% of respondents felt providing park-and-ride lot status deserved high priority.

+ The lowest ranked objective, only 18% rated as high, was to provide passenger loading estimates.

Finally, an additional goal noted by one respondent, was to provide " improved signage and schedule information" .

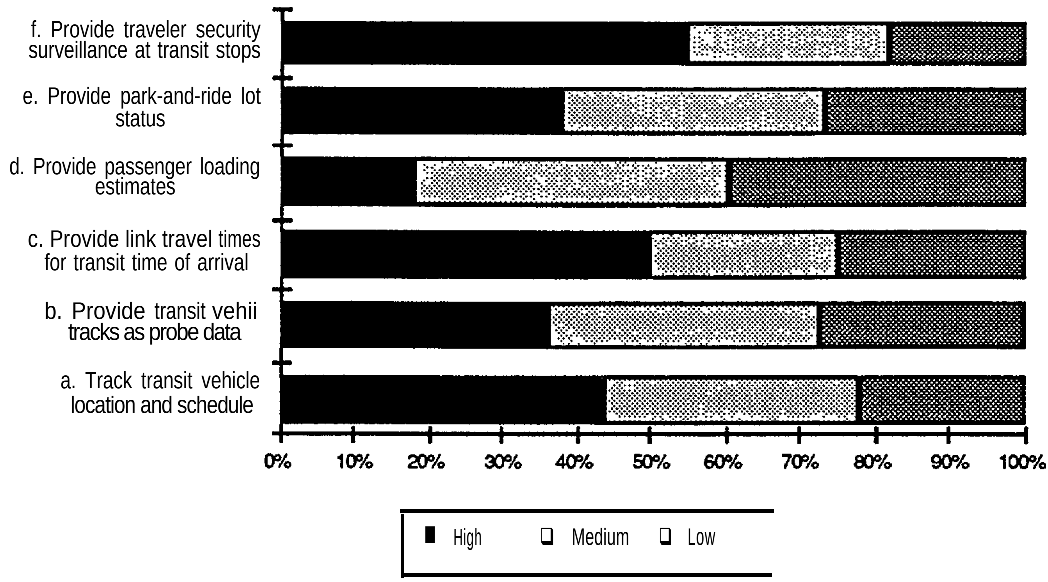

Figure 2-25. Objectives to Improve Multi-Modal and Inter-Modal Transportation Operations - Distribution of Responses from All Agencies

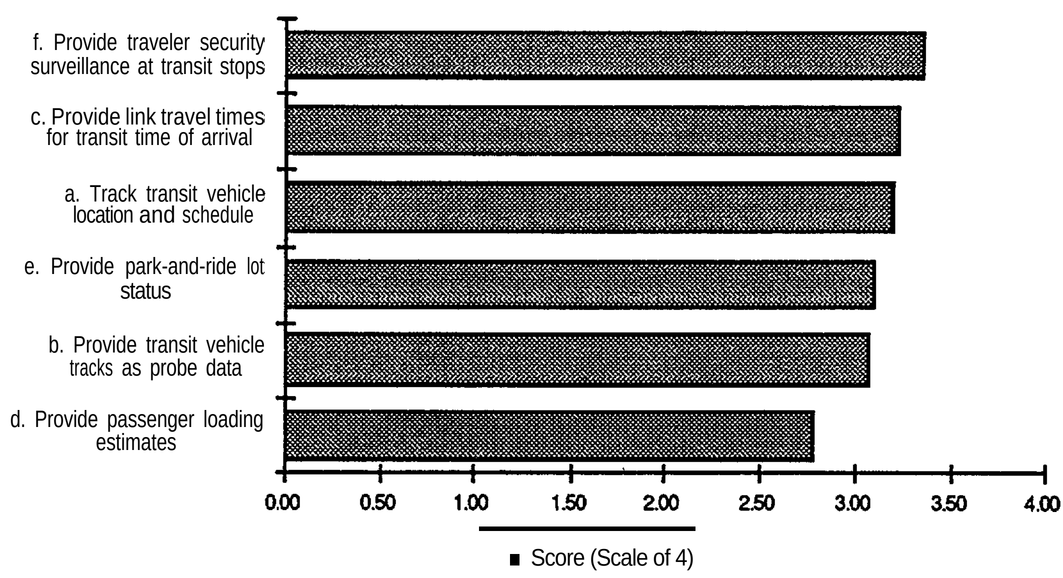

Figure 2-26. Objectives to Improve Multi-Modal and Inter-Modal Transportation Operations - Ranking Derived from All Responses

Goal 7 Enhance Transportation Systems Planning Database

Figures 2-27 and 2-28 summarize the results for the objectives to enhance the transportation systems planning database, the third lowest ranked SR/T goal. From the graphics, the following conclusions can be made:

+ The objectives of providing incident data (location, type, severity) and traffic count data had the most number of respondents assigning high rating (72% and 66%, respectively). The overall ranking, shown in Figure 2-28, also supports the conclusion that these objectives are most important with respect to transportation planning databases.

+ Providing delay, VMT, and traffic composition data were the next three highest ranked objectives with "high" ratings of 56%, 48%, and 55%, respectively.

+ The least significant objective to enhance the transportation database was to provide origin-destination data. Only 29% of respondents associated this data element with high priority.

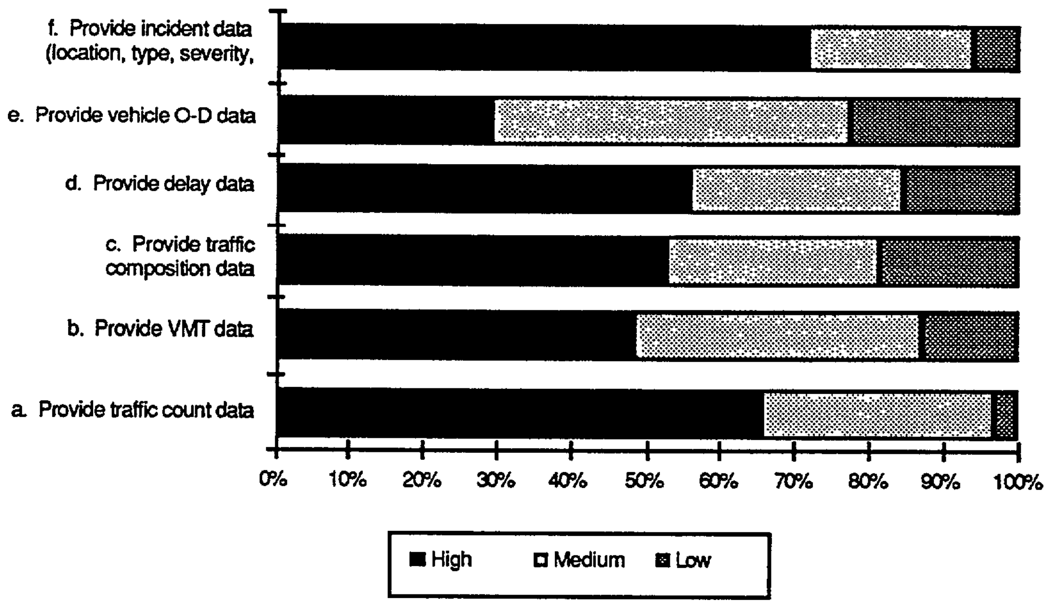

Figure 2-27. Objectives to Enhance Transportation Systems Planning Database - Distribution of Responses from All Agencies

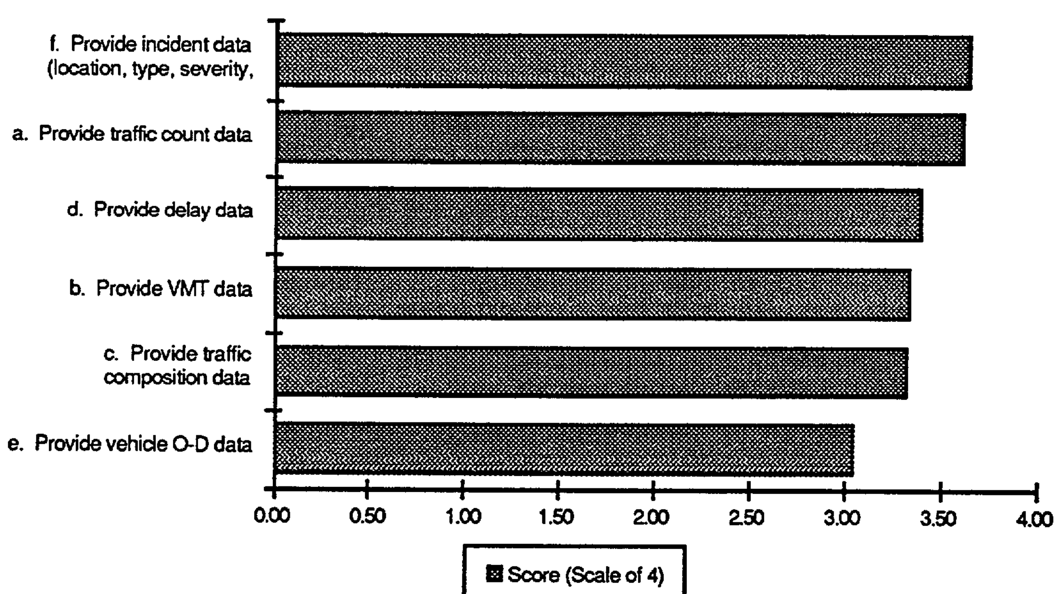

Figure 2-28. Objectives to Enhance Transportation Systems Planning Database - Ranking Derived from All Responses

Goal 8 - Support Traveler Information Services

Figures 2-29 through 2-32 summarize the results for the objectives to support traveler information services, the fifth most important goal to ail agencies. For analysis and reporting purposes, the responses to this section have been segregated into two groups:

1. All respondents.
2. Transit and Modal Agency respondents.

Based on this grouping, the following inferences can be made:

+ Providing traffic conditions information (e.g., congestion, incident) is the most important objective to both groups; 84% of all respondents and 100% of transit agencies ranked this as " high."
+ Providing roadway conditions information is the second highest priority objective for all respondents; 64% of respondents ranked this as " high."
+ On the other hand, transit agencies reported that providing inter-urban and urban mass transit information as well as roadway conditions information are all equal in importance. Forty percent of respondents ranked each of these 3 objectives as " high."
+ Providing parking information (e.g., park-and-ride) was the least important objective;.only 36 percent of the respondents rated this as " high."

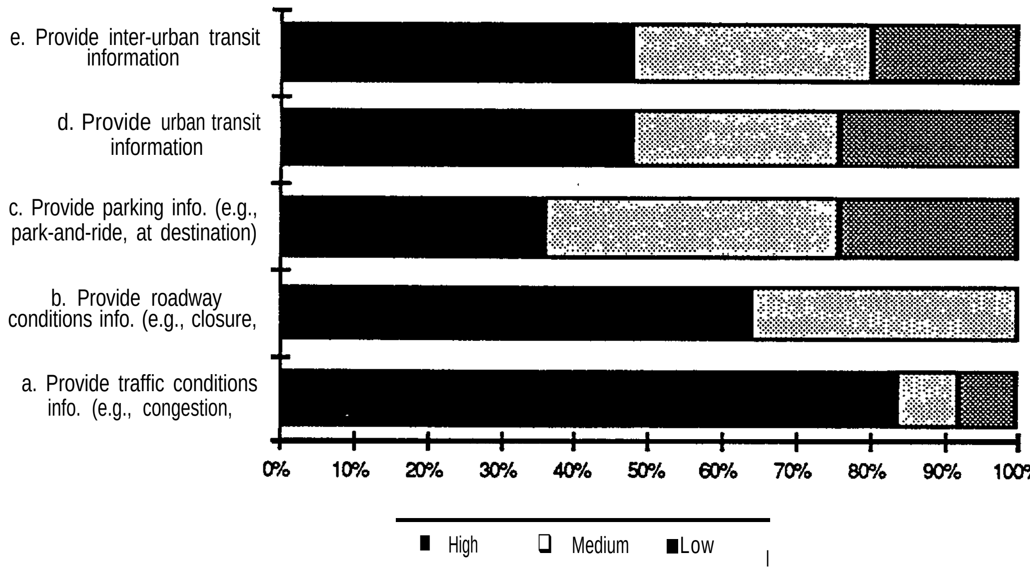

Figure 2-29. Objectives to Support Traveler Information Services - Distribution of Responses from All Agencies

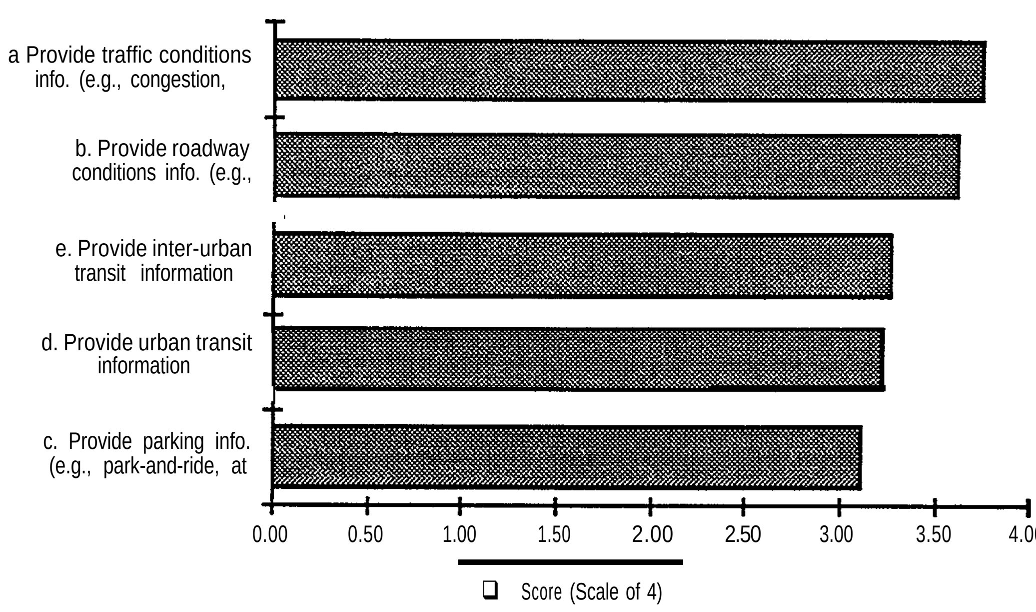

Figure 2-30. Objectives to Support Traveler Information Services - Ranking Derived from All Responses

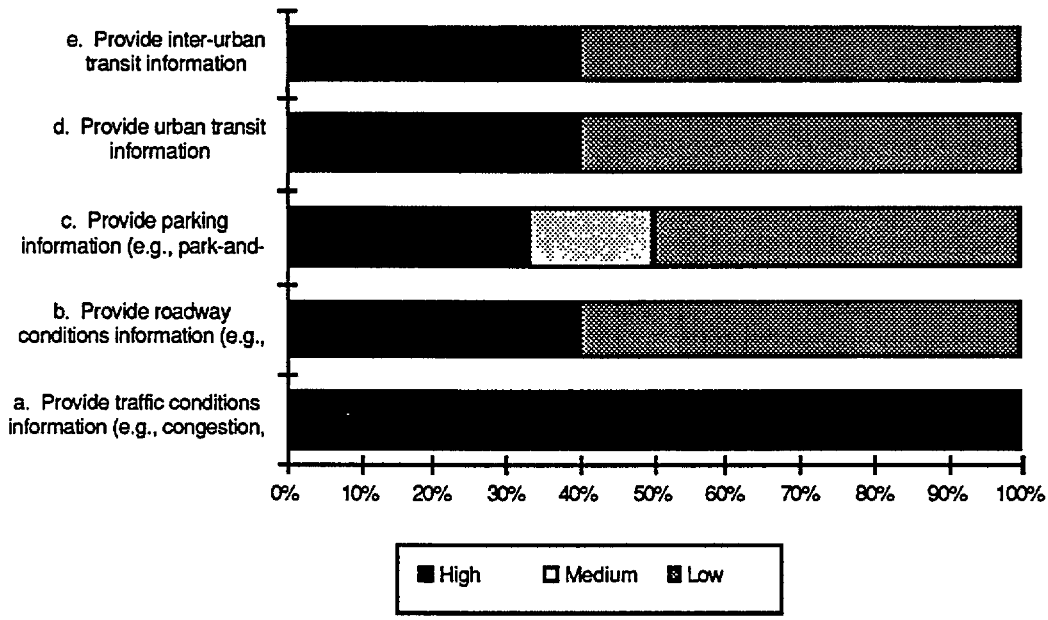

Figure 2-31. Objectives to Support Traveler Information Services - Distribution of Responses from Transit Agencies

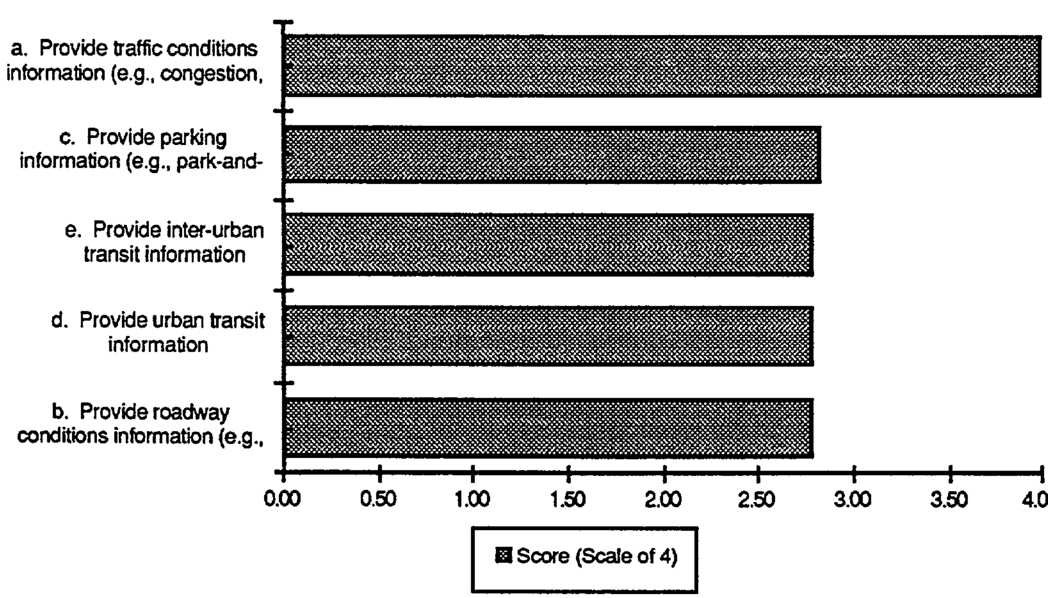

Figure 2-32. Objectives to Support Traveler Information Services - Ranking Derived from Transit Agencies

2.2.2.3 Technology Survey Results

For the technology survey, respondents were asked to rate the types of surveillance and technologies that will be used in their jurisdiction in the short-term (0-5 years) and in the long-term (5-20 years). The long-term responses, it is assumed, are likely to change and/or be influenced from technological advances and results from field operation tests (FOTs).

Surveillance Technology

Figures 2-33 and 2-34 summarize the results for the short-term surveillance technology vision. These results reflect the responses from all surveyed Coalition members. From the graphics, the following inferences can be made:

+ As expected, the use of vehicle detectors and human surveillance from police patrols were the two highest ranked techniques. Over 96% of respondents ranked the use of vehicle detectors as " high" and 77% for the use of human surveillance in the form of police patrol.

+ The use of commercial traffic reports was the second highest rank. Over 64% respondents ranked this as ' high."

+ The use of pavement surface conditions (dry/wet/icy) sensor and CCTV were the next two highest ranked objectives.

  Approximately 64% of the respondents ranked pavement surface condition sensors as high. This result is understandable given the role that weather conditions have in the Corridor and their associated effects on traffic. As one respondent noted, " when it rains it [traffic] stops!" .

  Approximately 61% of the respondents ranked CCTV as high.

+ The lowest ranking was environmental air quality (only 16% rated as high) and aerial surveillance (20% rated as high). The low rating associated with monitoring air quality is only partially understandable, since, from a priority point of view the reduction of congestion (by installing vehicle detectors to better manage traffic and to provide real-time traffic conditions to travelers to allow them to change route, time of travel, mode, etc.) will ultimately improve air quality. The low rating associated with the use of aerial surveillance is interesting, especially considering the size of the Corridor, the number of airports, and ability of aircraft' s to monitor traffic area-wide.

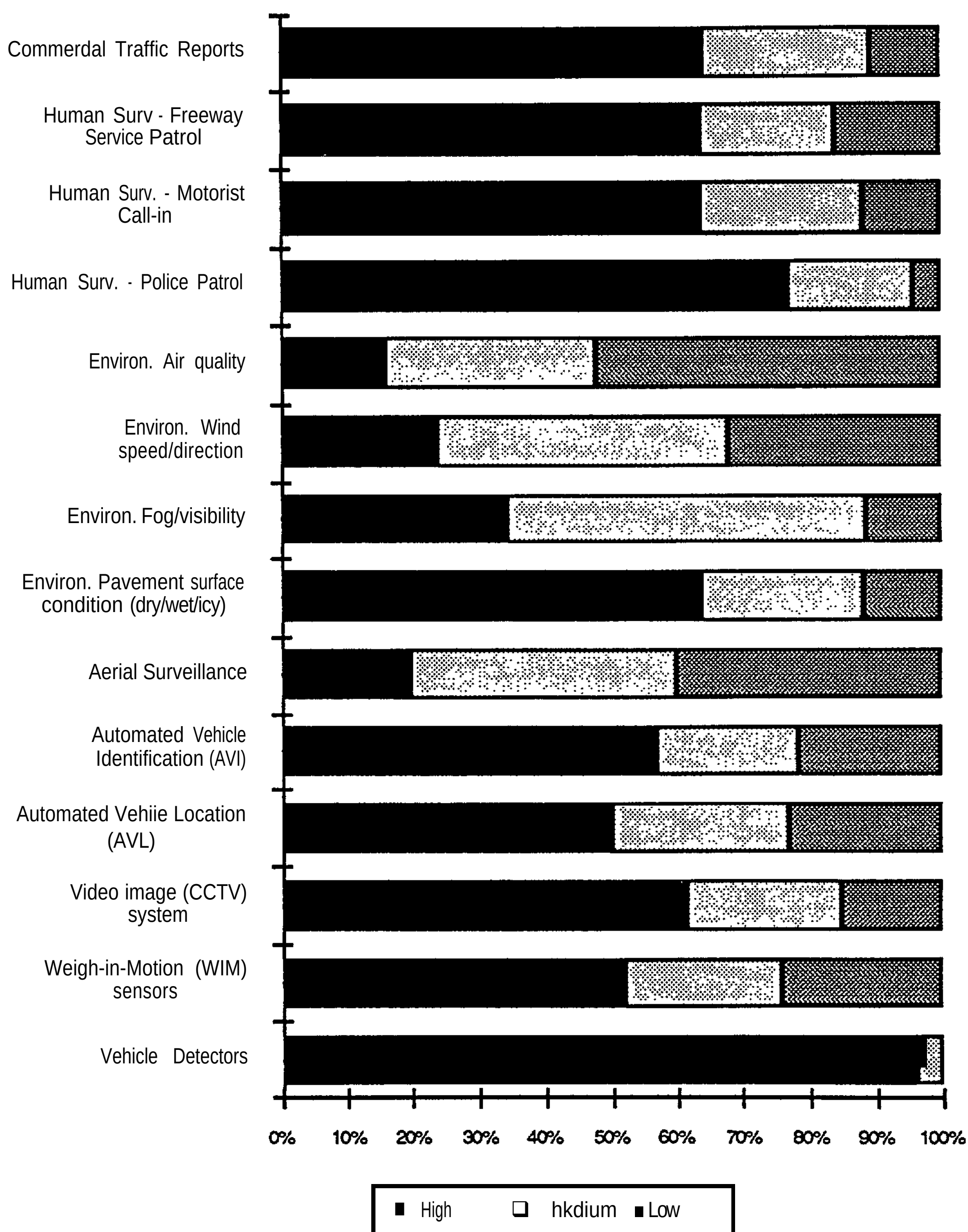

Figure 2-33. Short-Term Surveillance Technology Vision - Distribution of Responses from All Agencies

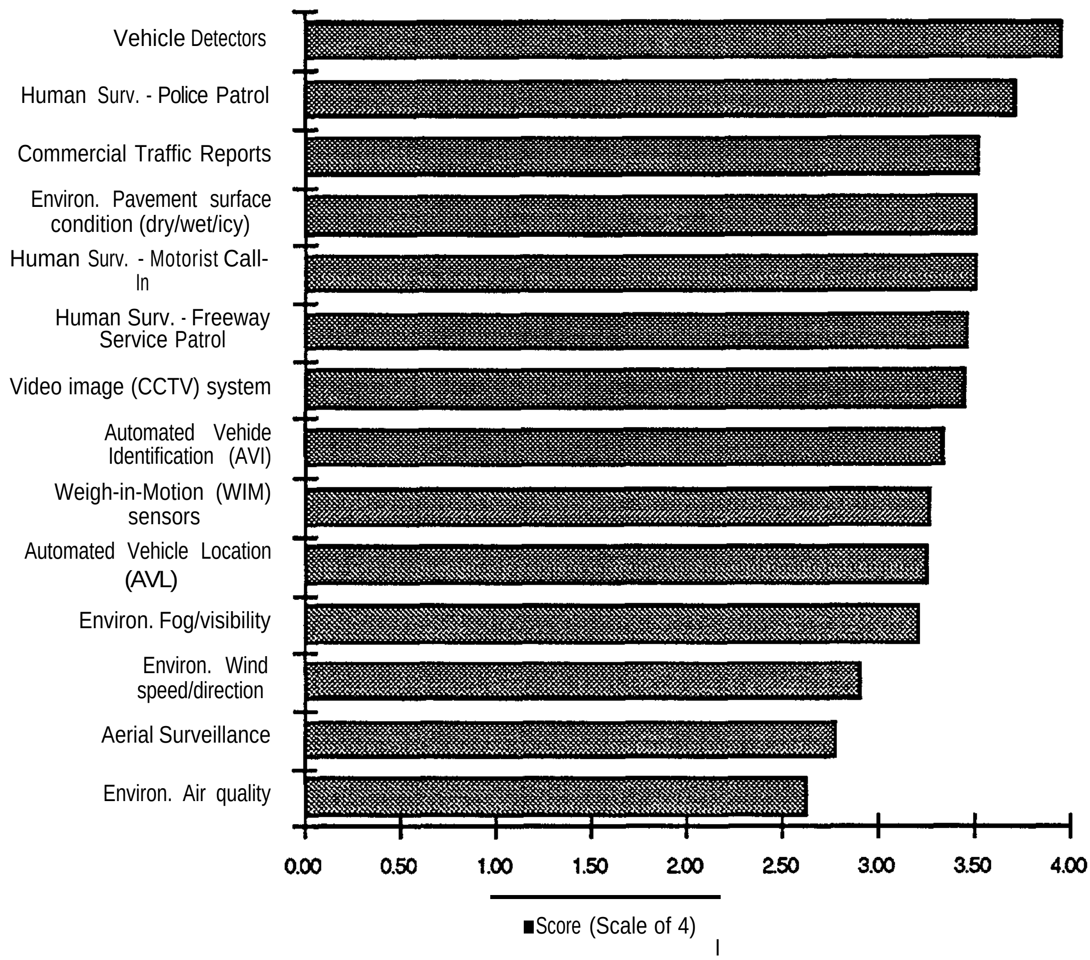

Figure 2-34. Short-Term Surveillance Technology Vision - Ranking Derived from All Responses

Figures 2-35 and 2-36 summarize the results for the long-term surveillance technology vision. These results reflect the responses from all surveyed Coalition members. From the graphics, the following inferences can be made:

+ With respect to the short-term responses, the use of environmental pavement surface conditions (dry/wet/icy) and the use of CCTV systems will become more important. The responses to the use of environmental pavement surface conditions ranked from 64% in the short-term to 76% in the long-term.Responses to the use of CCTV systems ranked from 65% in the short-term to 64% in the long-term.

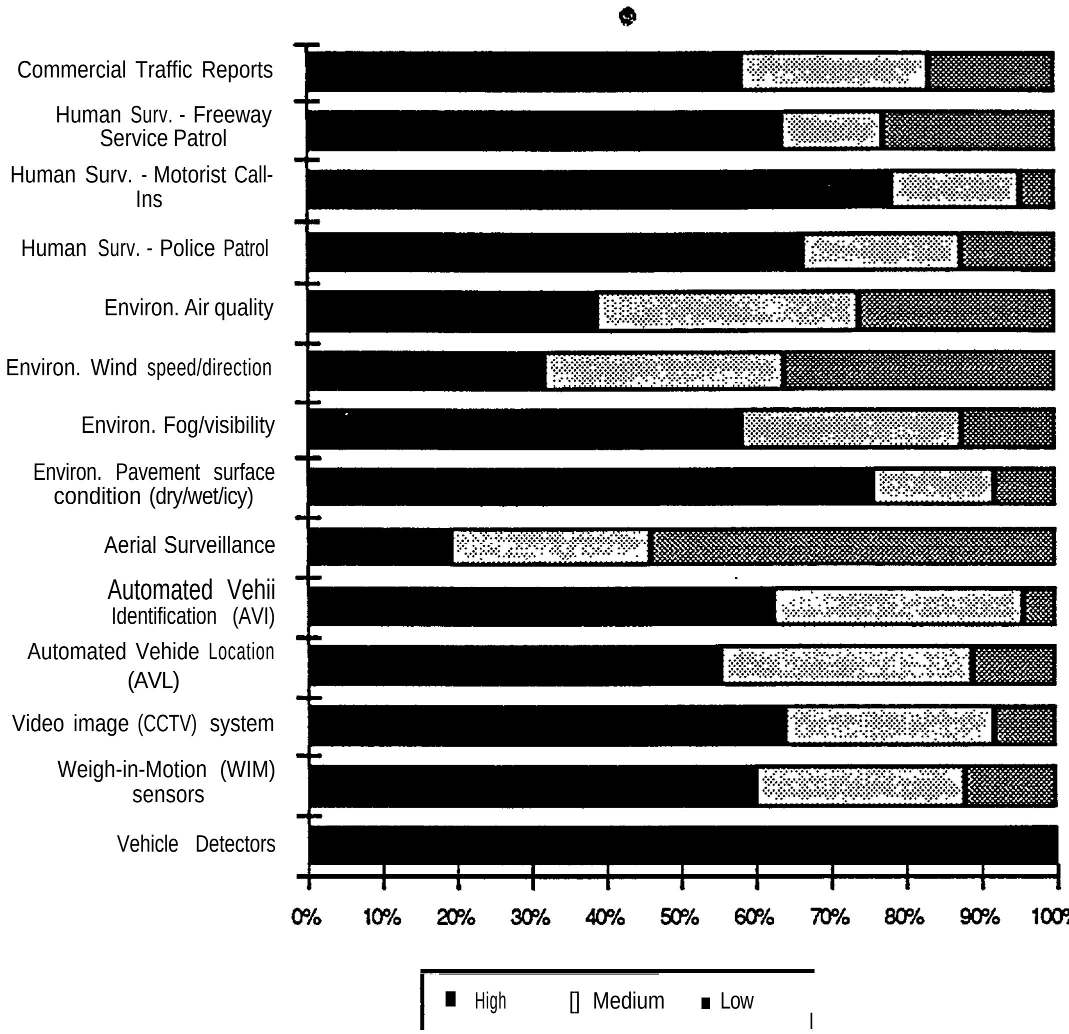

Figure 2-35. Long-Term Surveillance Technology Vision - Distribution of Responses from All Agencies

+ Vehicle detectors will remain same in priority with 76% high rating.

+ Also of note is the increase in emphasis being placed on air quality in the future. Responses to the use of environmental sensors to determine air quality moved from 16% in the short-term to 39% in the long-term.

+ The use of human surveillance in the long-term will continue to be widely used. Motorist call-ins will be used more frequently (up from 64% to 78%) - presumably as the use of cellular telephone increases.

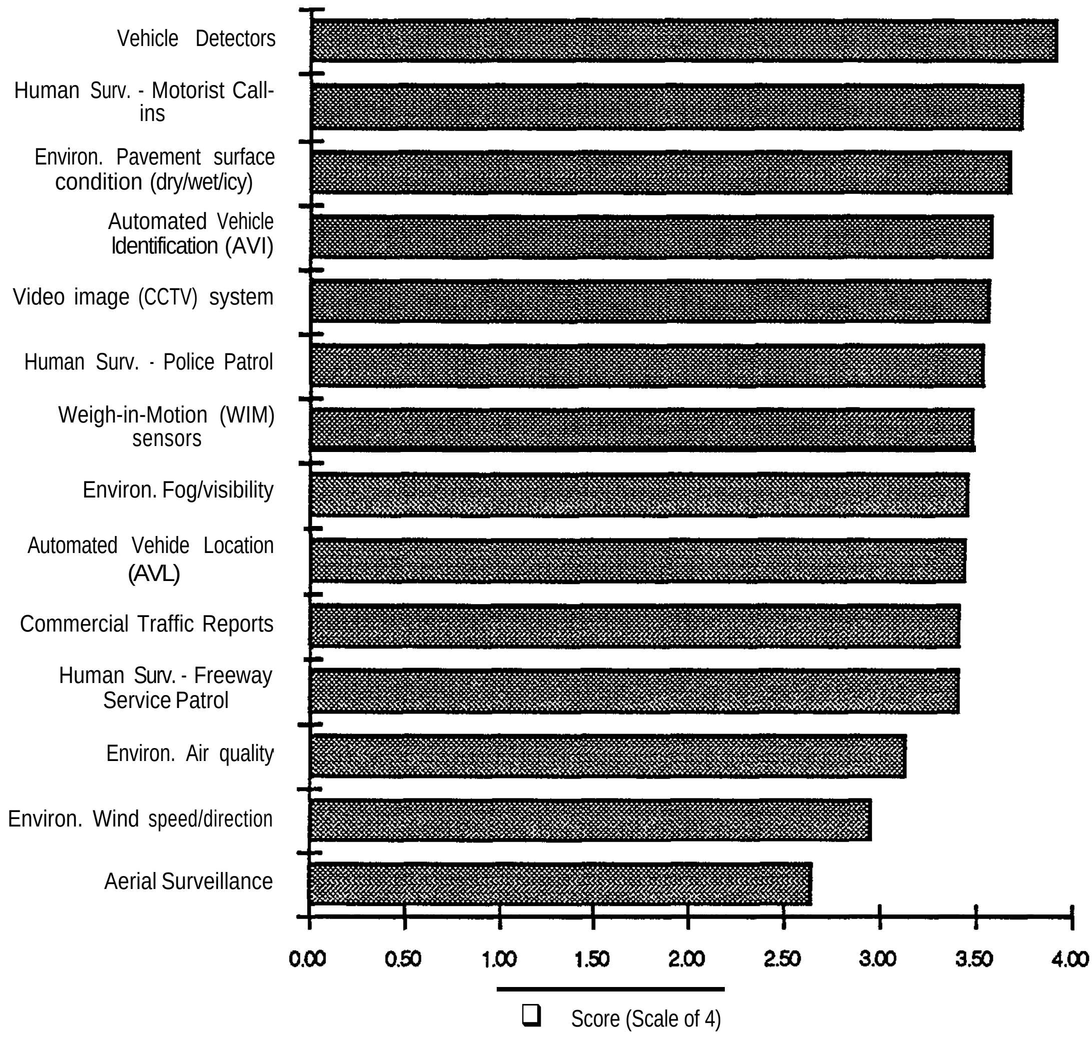

Figure 2-36. Long-Term Surveillance Technology Vision - Ranking Derived from All Responses

Additional goals/comments, noted by several respondents are as follows:

+ The use of video imaging will be high.
+ The use of cellular phones to generate vehicle probe data will be high.
+ The use of trucker' s radio to report erratic drivers, incidents will be used.

Detector Technology

Figures 2-37 and 2-38 summarize the results for vehicle detection technologies. These results reflect the responses from all surveyed Coalition members. From the graphics, the following inferences can be made:

- As expected, the use of inductive loop detectors was the highest in ranking. Over 92% of respondents ranked the use of inductive loop detectors as high.
- The use of microwave radar and video image processing were the second and third highest priority detectors, respectively. Approximately 67% of respondents ranked the use of both these sensors as high.
- The use of magnetic detectors and magnetometers were the lowest in terms of priority. Only 12% indicated the use of magnetic detectors was high and only 1 respondent indicated that magnetometers were high.

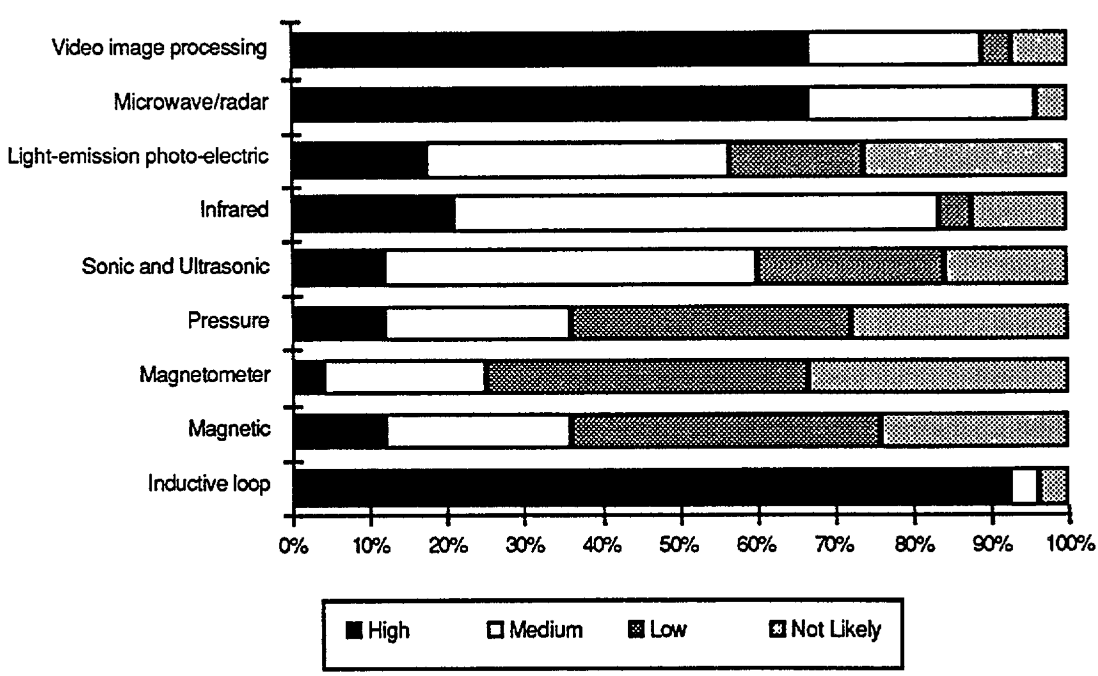

Figure 2-37. Technology Vision - Alternative Vehicle Detectors - Distribution of Responses from All Agencies

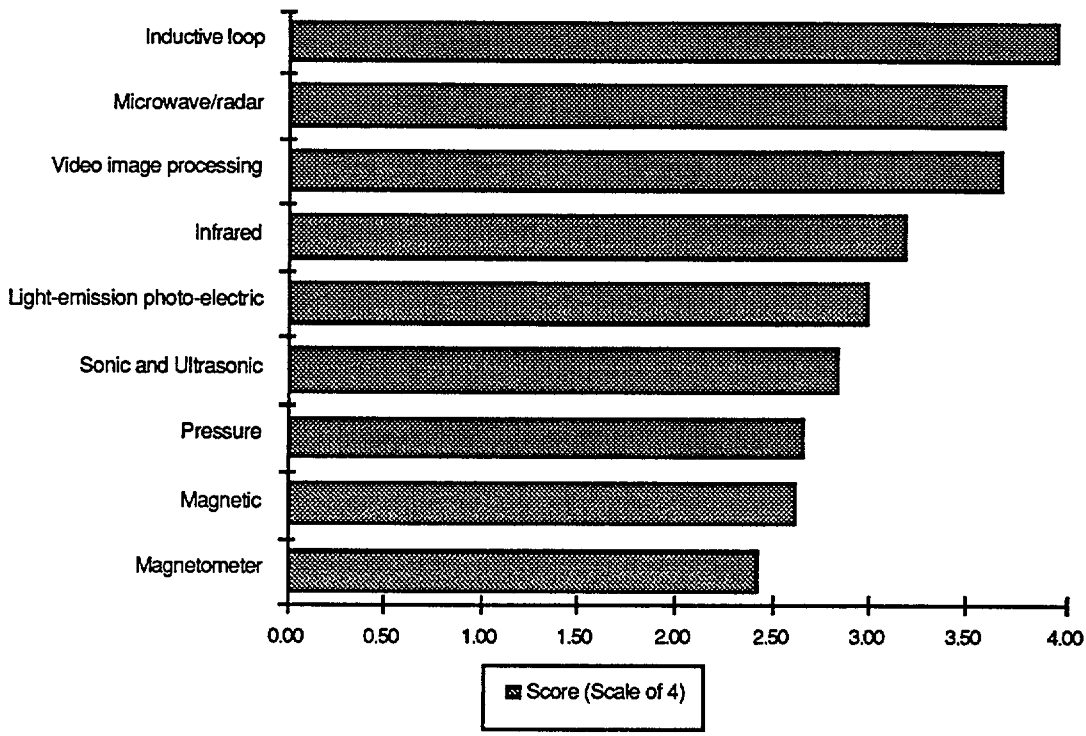

Figure 2-38. Technology Vision - Alternative Vehicle Detectors - Ranking Derived from All Responses

2.2.2.4 Public/Private Partnership Survey Results

Implementing and operating ITS technologies will place an extra burden of funding for each of the public agencies within the I-95 Corridor Coalition. In an attempt to minimize this burden, the Coalition has committed to fostering public/private partnerships that intend to capitalize on the technology, service or facility opportunities available from private companies. To understand how the public and private sector will interact with respect to a SR/T partnership, several questions were asked regarding: (1) current involvement with private organizations; (2) the role of the private sector; (3) the feasibility of a surveillance partnership; and (4) challenges to partnering. In this section, the results from surveys will be presented from two points of view:

1. Public Agencies.

2. Private Sector.

Public/Private Partnership Results from Surveyed Public Agencies

In the following sections, data obtained from survey questions to public agencies regarding the public/private partnerships are summarized. This data reflects the public agencies point of view on the subject matter.

Figures 2-39 through 2-43 summarize the results for the public/private partnerships. These results reflect the responses from all surveyed Coalition members. From the graphics, the following inferences can be made:

+ Fifty five percent of the respondents currently have existing relationships with various private sector companies. For the most part these relationships are with various commercial traffic reporting firms (e.g., Metro, Shadow, and so on).

+ Seventy eight percent of the respondents view the role of the private sector as either significant or very significant in supplementing traffic surveillance in the I-95 Corridor.

+ Eighty five percent of the respondents favor a public/private partnership with respect to acquiring and providing surveillance information.

+ In terms of challenges facing public/private partnerships, public agencies reported that funding arrangements and liabilities were their overriding concerns.Fifty percent of the respondents viewed funding as a high concern and over 42 percent view liability as a high concern. This is consistent with much of the existing literature regarding these relationships. Responsiveness to each other' s concerns and the ability to maintain a long-term partnership were not viewed as significant challenges.

Additional comments/concerns, noted by several respondents are as follows:

1. The identification of contributions/benefits for each party is important.

2. There are organization hurdles to be overcome.

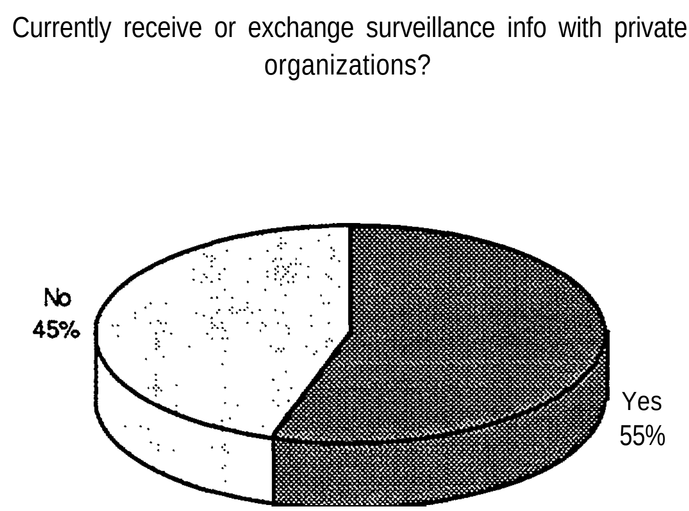

Figure 2-39. Current Involvement with Private Organizations - Distribution of Responses from All Agencies

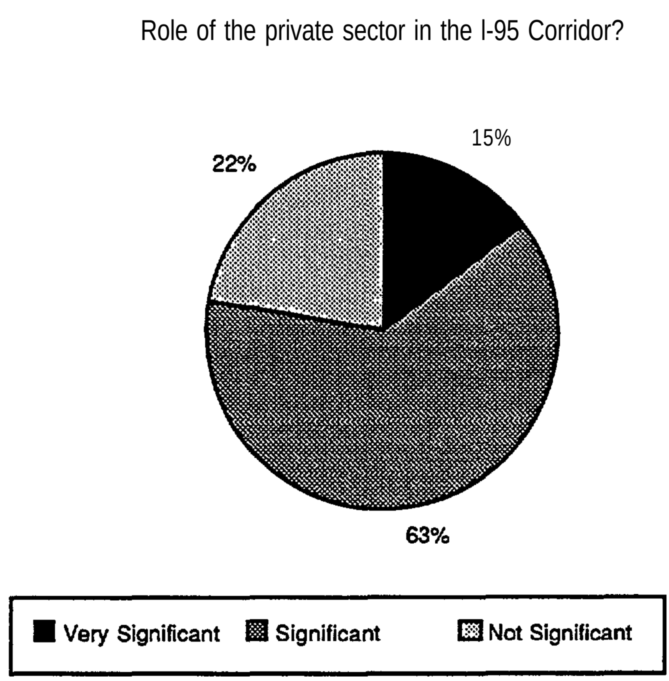

Figure 2-40. The Role of the Private Sector -Distribution of Responses from All Agencies

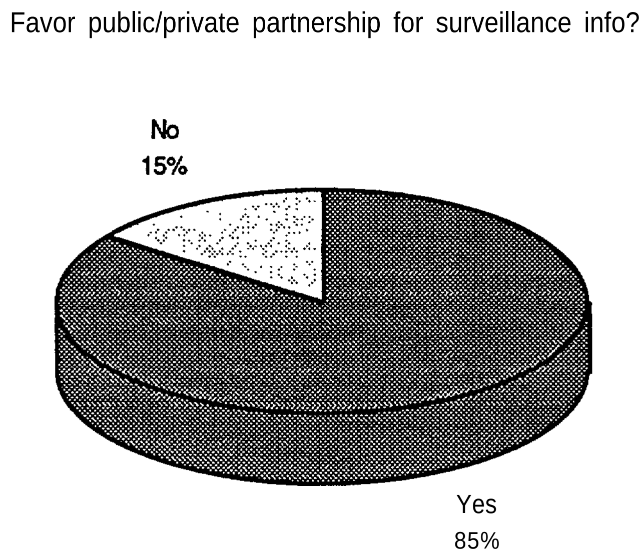

Figure 2-41. A Partnership for Surveillance - Distribution of Responses from All Agencies

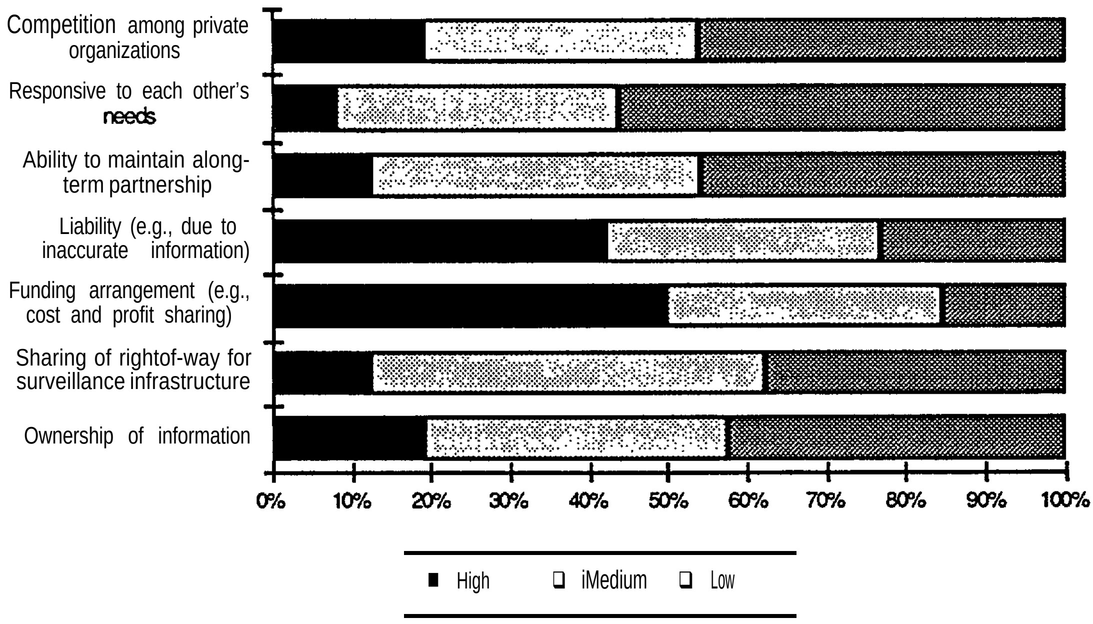

Figure 2-42. Public/Private Partnership Challenges - Distribution of Responses from All Agencies

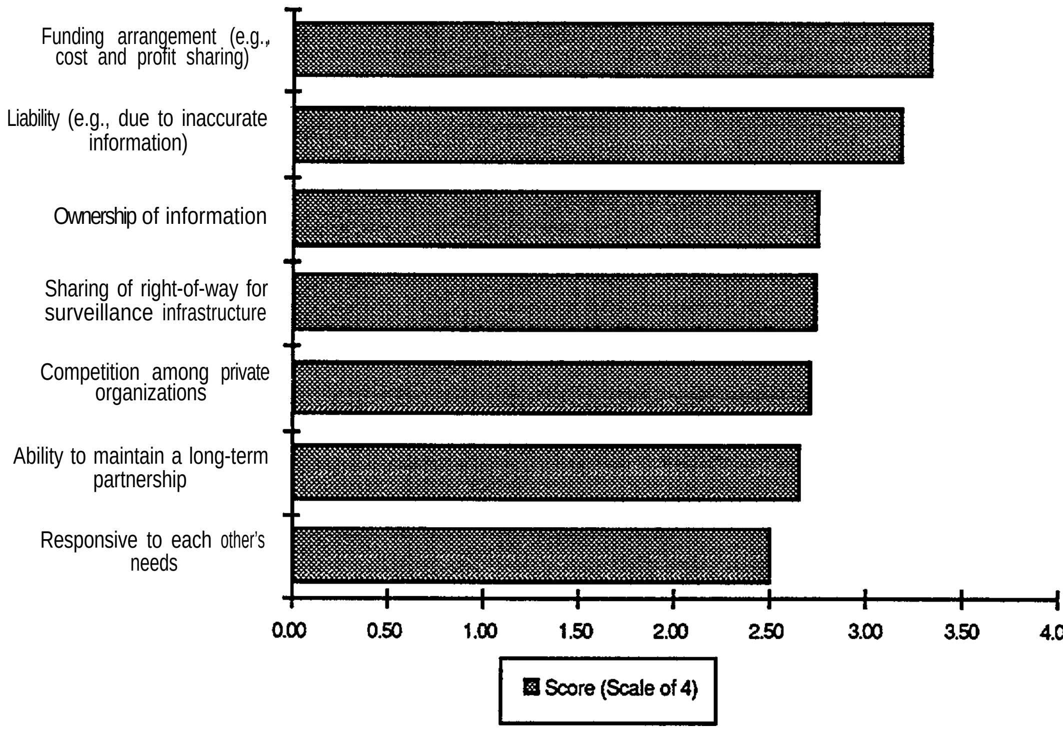

Figure 2-43. Public/Private Partnership Challenges - Ranking Derived from All Responses

Public/Private Partnership Results from the Private Sector

In the following sections, data obtained from survey questions to private companies with respect to the public/private partnerships are summarized. This data reflects the private companies point of view on the subject matter.Surveys available as of the time of this document were limited; results include mainly commercial traffic reporting firms. In some cases, additional private sector companies refused to participate in the survey or did not respond.

The results from the private sector responses are summarized below:

+ The respondent favored a public/private partnership currently has existing partnerships in place with the public sector.

+ The main challenge expressed by the private sector was to have public agencies streamline their decision making process. Additional concerns were raised regarding the definition of roles for the private sector.

+ Technological capability was desired.

+ Return on investment was not a major concern.

2.3 GOAL AND OBJECTIVE IDENTIFICATION: LITERATURE REVIEW

To identify a comprehensive set of surveillance system goals and objectives, a review of related literature was conducted. This section summarizes the results of the literature review, covering the on-going ITS initiatives at the national level, the ISTEA management systems, and the state ITS initiatives.

2.3.1 National Program Plan for ITS

The ISTEA established the ITS Program in Sections 6051 through 6059 with the following goals:

+ Enhance the capacity, efficiency, and safety of the highway system, serving as an alternative to additional physical capacity.

+ Enhance efforts to attain air quality goals set by the Clean Air Act.

+ Reduce societal, economic, and environmental costs caused by congestion.

These goals have evolved and expanded in the past few years to reflect the vision and needs of our nation’ s transportation systems. The initial set of ITS goals and objectives were documented in May, 1992 in IVHS America’ s *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States.* This set was modified to more clearly convey the ITS vision in the USDOT’ s *IVHS Strategic Plan --Report to Congress* in December, 1992. The most recent ITS goals and objectives were provided in the draft version of the *National Program Plan for Intelligent Vehicle-Highway Systems* by IVHS America in May, 1994. With this evolution and knowledge gained from the Nationwide IVHS Architecture Development studies, the ITS goals and objectives have become more definitive (refer to Table 2-5) to better guide the implementation of ITS services.

Table 2-5. ITS National Goals **and** *Objectives*

ITS GOALS	ASSOCIATED OBJECTIVES
Improve Safety	- Reduce the number of motor vehicle collisions, and associated injuries and fatalities - Improve the response time of emergency medical services - Improve the ability to handle HAZMAT incidents - Enhance traveler security and road service responsiveness
Increase Efficiency	- Increase efficiency by smoothing flows - Increase average vehicle occupancy - Increase capacity of existing facilities - Reduce vehicle miles traveled - Reduce time lost in intermodal interchange - Reduce delay associated with congestion
Reduced Energy and Environmental Impact	- Reduce harmful emissions per unit of travel - Reduce energy consumption per unit of travel - Reduce new right-of-way requirements and community disruption - Reduce fuel wasted - Enhance efforts to attain air quality goals
Enhance Productivity	- Reduce cost incurred by fleet operators - Reduce cost and improve equity of fee collection - Reduce delays and cost of regulating vehicles - Reduce cost and improve quality of data collection - Reduce travel time - Reduce cost to transportation-dependent industries
Enhance Mobility	- Improve accessibility to intermodal transportation - Improve quality of travel options information - Improve mode choice options - Improve travel time predictability - Improve transportation affordability - Reduce travel stress

To achieve the national ITS goals and objectives, the implementation of all ITS user services is necessary. To date, a total of 29 user services (including the recently defined Emissions Testing and Mitigation service) in 6 separate functional areas have been defined [IVHS America, May 1994]. Among these user services, 19 of them would require some kind of surveillance information to function (refer to Table 2-6). Thus, goals and objectives for this SR/T Project must be identified to develop these services at the national level.

Table 2-6. ITS User Services Requiring Surveillance Information

User Services	Required Surveillance Information
Travel and Traffic Management	
Pre-Trip Travel Information	Traffic and weather conditions
En-Route Driver Information	Traffic and weather conditions
Route Guidance	Traffic and weather conditions
Ride Matching and Reservation	None
Traveler Service Information	None
Incident Management	Incident location and severity, traffic condition, emergency vehicle location
Traffic Demand Management	Historical traffic and environmental data
Traffic Control	Traffic and air quality
Emissions Testing and Mitigation	Air quality
Public Transportation Management	
En-Route Transit Information	Traffic and weather conditions
Public Transportation Management	Traffic condition and vehicle location
Personalized Public Transit	Traffic condition and vehicle location
Public Travel Security	Facility and people surveillance
Electronic Payment Services	Vehicle identification
Commercial Vehicle Operation	
Commercial Vehicle Electronic Clearance	Vehicle identification
Automated Roadside Safety Inspection	Vehicle identification
Commercial Vehicle Administrative Processes	None
Onboard Safety Monitoring	None
HAZMAT Incident Response	Vehicle and cargo identification, and traffic conditions
Commercial Fleet Management	Traffic condition and vehicle location
Emergency *Vehicle Management*	
Emergency Notification and Personal Security	Collision detection and location
Emergency Vehicle Management	Traffic condition, vehicle identification, and vehicle location
Advanced Vehicle Safety Systems	
Longitudinal Collision Avoidance	Traffic condition, traffic queue, stopped vehicle
Lateral Collision Avoidance	None
Intersection Collision Avoidance	Approaching vehicle detection and identification
Vision Enhancement for Crash Avoidance	None
Safety Readiness	None
Pre-Crash Restraint Deployment	None
Automated Vehicle Operation	Future role depends on exploration of AHS concepts.

2.3.2 ISTEA Management and Monitoring Systems

ISTEA mandated that all of the states implement the following management and monitoring systems (49 CFR Part 614) by the beginning Federal Fiscal year 1995:

+ Pavement Monitoring System (PMS).
+ Bridge Management System (BMS).
+ Safety Management System (SMS).
+ Congestion Management System (CMS).
+ Public Transportation Management System (PTMS).
+ Intermodal Management System (IMS).

All these management systems require extensive data collection efforts, necessitating the implementation of a Traffic Monitoring System (TMS) to collect traffic data. A significant portion of the data comes from surveillance systems; thus the necessity to understand how they influence the development and implementation of the I-95 Corridor-wide surveillance system. The purpose of this paragraph is to briefly describe these six management and the major requirements to be considered to identify the goals and objective of a Corridor-wide surveillance system.

2.3.2.1 Pavement Monitoring System

The *Federal Register* (dated December 1, 1993) provides the following definition of a PMS:

> " Pavement management system (PMS) means a systematic process that provides, analyzes, and summarizes pavement information for use in selecting and implementing cost-effective pavement construction, rehabilitation, and maintenance programs."

The PMS requires development of a large database for the National Highway System (NHS) to include: the physical pavement features, such as number of lanes, lane width, and roadway length; pavement condition surveys, such as ride, distress, rutting, and surface friction;

construction and maintenance records; and traffic information. Although the pavement condition itself is emphasized, the traffic information needs for PMS are substantial, including volume, classification, and load data specific to the road segments.

2.3.2.2 Bridge Management System

The *Federal Register* (dated December 1, 1993) provides the following definition of a BMS:

> "Bridge management system (BMS) means a decision support tool that supplies analyses and summaries of data, uses mathematical models to make predictions and recommendations, and provides the means by which alternative policies and programs may be efficiently considered. A BMS includes formal procedures for collecting, processing, and updating data, predicting deterioration, identifying alternative actions, predicting costs, determining optimal policies, performing short- and long-term budget forecasting, and recommending programs and schedules for implementation within policy and budget constraints."

This system does not directly require traffic data. However, it requires a database of bridge inventory, inspection, cost, and supplemental data. It also requires a rational and systematic procedure to apply network level analysis and optimization to the bridge inventory. The multi-period optimization in this process requires a user cost analysis which, in turn, requires traffic data and growth rate.

2.3.2.3 Safety Management System

The *Federal Register* (dated December 1, 1993) provides the following definition of an SMS.

> "Highway safety management system (SMS) means a systematic process that has the goal of reducing the number and severity of traffic crashes by ensuring that all opportunities to improve highway safety are identified, considered, implemented as appropriate, and evaluated in all phases of highway planning, design, construction, maintenance, and operation: and by providing information for selecting and implementing effective highway safety strategies and projects."

The SMS introduces a systematic approach in the following areas to ensure safety:

a. Coordinating and integrating broad-base safety programs (motor carrier, corridor, and so on).

b. Identifying and investigating hazardous highway locations (similar to the established Highway Safety Improvement Program.

c. Ensuring early consideration of safety in all highway projects.

d. Identifying the safety needs of special user groups (pedestrians, HAZMAT carriers, etc.) during plan, design, and construction.

e. Routinely maintaining and upgrading highway safety appurtenances.

Of these five items, item b. is data-intensive. The determination of high-accident locations and the subsequent investigation primarily requires highway accident data as well as traffic volume data for accident rates calculation. While the accident data are currently obtained from the police department' s records, under a matured ITS, these data may be available from incident reports from traffic management systems. Thus, SMS levies requirements for surveillance systems for traffic volume and potentially accident data.

2.3.2.4 Congestlon Management System

The *Federal Register* (dated December 1, 1993) provides the following definition for the CMS and related terminology.

> " Congestion Management System (CMS) means a systematic process that provides information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods. A CMS includes methods to monitor and evaluate performance, identify alternative actions, assess and implement cost-effective actions, and evaluate the effectiveness of implemented actions.Congestion is defined as the level at which transportation system performance is no longer acceptable due to traffic interference. The level of acceptable system performance may vary by type of transportation facility, geographic location (metropolitan area or sub-area, rural area) and/or time of day."

The CMS requires that the states establish a continuous program for data collection and system monitoring to determine and monitor the duration and magnitude of congestion, thereby requiring traffic surveillance data.The CMS also calls for consideration of strategies, or combination of strategies to alleviate congestion problems. Implementation of several of these strategies would require surveillance information. Although these strategies are high-level at this time, an attempt was made to identify their impacts on surveillance systems (refer to Table 2-7). Note that the strategies in Table 2-7 are not mandated for implementation, but are needed to be considered for implementation, if deemed feasible; Therefore, the subsequent requirements on the surveillance systems are not mandatory at this time.

Table 2-7. Impact of CMS Strategies on Surveillance Requirements

CMS Strategy	Impacts on Surveillance Systems
Transportation demand management measures, such as car or vanpooling, alternative work hours, telecommuting, and parking management.	- Requires historic traffic data.
Traffic operational improvements, such as intersection and roadway widening, channelization, traffic surveillance and control systems, motorist information systems, ramp metering, traffic control centers, and computerized signal systems,	- Requires historic and real-time traffic data. - Requires deployment of traffic surveillance system at the congestion locations.
Measures to encourage HOV use, such as HOV lanes, HOV ramp bypass lanes, guaranteed ride home programs, and employer trip reduction ordinances.	- Requires historic traffic and travel time data. - Requires vehicle occupancy data (persons per vehicle).
Public transit capital improvements, such as exclusive right-of-ways (rail, busways, bus lanes), bus bypass ramps, park-and-ride and mode change facilities, and paratransit services.	- Requires historic and real-time traffic data for effective dispatching. - Requires parking availability data.
Public transit operational improvements, such as service enhancement or expansion, traffic signal preemption, fare reduction, and transit information systems.	- Requires AVI technology for signal priority. - Requires AVL technology for fleet management and traveler information.
Measures to encourage the use of nontraditional modes, such as bicycle facilities, pedestrian facilities, and ferry service.	Not related.
Congestion pricing.	Requires real-time and historical traffic data.
Growth management and activity center strategies.	Requires historical traffic data for strategy development.
Access management techniques (related to property access).	Not related.
Incident management.	Requires incident detection, verification, and emergency vehicle route guidance technologies.
IVHS and advanced public transportation system technology.	Requires various surveillance technologies.
General purpose lanes.	Not related.

2.3.2.5 Public Transportation Management System

The *Federal Register* (dated December 1, 1993) provides the following definition for the PTMS and related terminology.

> " Public transportation facilities and equipment management system means a systematic process that collects and analyzes information on the condition and cost of transit assets on a continual basis. It identifies needs as inputs to the metropolitan and statewide planning processes enabling decision makers to select cost-effective strategies for providing and maintaining assets in a serviceable condition.*Transit assets* means public transportation facilities (e.g., maintenance facilities, stations, terminals, transit related structures), equipment, and roiling stock."

A significant amount of data required for the PTMS relates to transit assets. However, PTMS also requires data from other management systems and vehicle ridership information from the TMS.

2.3.2.6 Intermodal Management System

The Federal Register (dated December 1, 1993) provides the following definition for the IMS and related terminology:

> " Intermodal facility means a transportation element that accommodates and interconnects different modes of transportation, and serves intrastate, interstate, and international movement of people and goods. Intermodal facilities include, but are not limited to, highway elements providing terminal access, coastal, inland and Great Lakes ports, canals, pipeline farms, airports, marine and/or rail terminals, major truck terminals, transit terminals including park-and-ride facilities, and intercity bus terminals.
>
> Intermodal system means a transportation network consisting of public and private infrastructure for moving people and goods using various combinations of transportation modes.

Intermodal Management System (IMS) means a systematic process of identifying key linkages between one or more modes of transportation, where the performance or use of one mode will affect another; defining strategies for improving the effectiveness of these modal interactions; and evaluation and implementation of these strategies to enhance the overall performance of the transportation system."

IMS requires coordination with the data collection effort for other management and monitoring systems. Performance measures will be established at the local levels. Strategies will be identified for intermodal efficiencies.Depending determination of performance measures and the selection of strategies, new surveillance information requirements may emerge.

2.3.2.7 Traffic Monitoring System

The *Federal Register* (dated December 1, 1993) provides the following definition for the TMS and the related terminology.

" Highway traffic data means data used to develop estimates of the amount of person or vehicular travel, vehicle usage or vehicle characteristics associated with a system of highways or with a particular location on a highway. These types of data support the estimation of the number of vehicles traversing a section of highway or system of highways during a prescribed time period (traffic volume), the portion of such vehicles that may be of a particular type (vehicle classification), the weights of such vehicles including the weight of each axle and associated distances between axles on a vehicle (vehicle weight), or the average number of persons being transported in a vehicle (vehicle occupancy).

Traffic monitoring system for highways means a systematic process for the collection, analysis, summary, and retention of highway related person and vehicular traffic data, including public transportation on public highways and streets."

This system provides data to the previously discussed six management systems, and as such, the data to be collected for this system are driven by the management systems. TMS requires a sufficient number of stations for the continuously count traffic volume, classify vehicles, and measure vehicle weight. The data will be analyzed to calculate a number of traffic parameters, such as growth factors, seasonal variations, Annual Average Daily Traffic (AADT), etc. Data on vehicle classification and vehicle occupancy are required for the NHS.

2.3.2.8 Summary of ISTEA impacts

The ISTEA-mandated management and monitoring systems impose data collection efforts on all transportation agencies. A significant portion of the necessary data are traffic-related and can be collected through automated and human surveillance methods (refer to Table 2-8). To comply with ISTEA means that the goals and objectives of the Corridor-wide surveillance system must address the needs of these management and monitoring systems.

Table 2-8. Surveillance Data Needs for Supporting ISTEA Management and Monitoring Systems

Management and Monitoring Systems	Surveillance Data Needs
Pavement Monitoring System	- Traffic volume - Vehicle classification - Axle load data
Bridge Management System	- Traffic volume - Traffic growth
Safety Management System	- Accident data - Traffic volume and movement
Congestion Management System	- Traffic data - AVI and AVL may be necessary depending on the strategies implemented
Public Transportation Management System	Passenger count data
Intermodal Management System	Data needs depend on the selection of performance measures and strategies to improve system efficiency
Traffic Monitoring System	- Volume - Classification - Vehicle weight - Vehicle occupancy data

2.3.3 State ITS Initiatives

Although many states are performing ITS early deployment studies to determine service needs in their state, only a few in the country have completed their studies.In the I-95 Corridor, only the Boston Area has completed its study, making it difficult to gain insights into the surveillance goals and objectives of other Coalition agencies through literature review. Thus, the identification of the l-95 Corridor-wide surveillance system goals and objectives should rely more on the survey results than on the existing literature.

The Boston Area ITS Early Deployment Study [Massachusetts Department of Transportation, 1994] stressed the importance of acquiring surveillance data to support incident detection, congestion monitoring, traveler information, and control strategy optimization. Specifically, this study calls for the following surveillance functions:

+ Roadway Detection System. Loop detectors and overhead-mounted microwave sensors are planned to collect vehicle speed, volume, and occupancy data. This system is also to detect over-height vehicles on approaches to the depressed Central Artery/Third Harbor Tunnel.

+ Vehicle Probes. Vehicle probes using AVI transponders are planned to collect real-time and direction-specific travel-time information.

+ Weather Surveillance. Accurate weather and road surface condition information (such as wet pavement, ice, snow, salted-slush, etc.) collection is planned. This information will be used to disseminate to travelers, and to plan roadway maintenance and salting activities.

+ Transit Monitoring The system plans to monitor, in real time, transit operational conditions by upgrading the current surveillance and control system.

This ITS plan also integrates the surveillance functions with the other traffic monitoring and control subsystems at a regional Traffic Information and Control Center.

Similar to the Boston Area, the New Jersey Department of Transportation has initiated an effort to develop a Regional Traffic Information Center (RTIC) for automatically linking the various ITS implementations of the state agencies [New Jersey Department of Transportation, December 1993], including:

+ TRANSCOM.
+ New Jersey Turnpike Authority.
+ New Jersey Highway Authority.
+ New Jersey Department of Transportation.
+ Port Authority of New York and New Jersey.
+ New Jersey Transit.
+ New Jersey State Police.

Although the primary focus of the RTIC is to share a wide spectrum of transportation operational information, acquisition of surveillance data using various technologies and techniques is also emphasized. Surveillance data collection and sharing categories include:

+ Sensor-based data on speeds and travel times.
+ Electronic Toil and Traffic Management (ETTM)-probe link travel times/speeds.
+ Real-time compressed video.
+ Snap-shot video images.
+ Weather station information.
+ Bus AVL link travel times.
+ Bus incident detection/confirmation.
+ Waiting times at toil booths.
+ Real-time construction schedule.
+ Incident report by toil collectors.
+ Local police notification.

Evidently, one objective of the RTIC effort is to maximize the utilization of existing resources (either by automated or manual means) to develop the regional surveillance information, which is consistent with the Coalition's goal.

Other states within the Corridor also have on-going ITS initiatives reported in the literature [IVHS America, April 1994], though with less detail. in the area of surveillance, the following observations were made:

+ Monitoring traffic flow for incident detection seems to be a top priority. The roles of inductive loop detectors and CCTV continue to be significant in this effort (e.g., 310 loop and overhead detectors combined, and 196 CCTVs are used in the Philadelphia Traffic and Incident Management System; and 21 CCTVs in Maryland).

+ New vehicle detection and surveillance technologies are being tested. Overhead detectors are tested and used in Pennsylvania, Maryland, New Jersey, and New York, to name a few. Virginia and Maryland jointly test the effectiveness of gathering probe data from cellular telephones. There are also efforts to examine other alternative detection technologies (such as fiber optics at Virginia Tech University).

+ WIM technologies are being tested in Pennsylvania to support (CVO) programs.

in summary, existing literature on state and regional ITS initiatives is very limited and, therefore, cannot contribute significantly to the identification of Corridor-wide surveillance system goals and objectives. As the research and development activities for the Corridor-wide surveillance system continue, efforts should be made to identify additional literature within the Corridor to help strengthen definition of these system goals and objectives.

2.4 RECOMMENDED CORRIDOR SURVEILLANCE GOALS AND OBJECTIVES

The purpose of this section is to recommend the goals and objectives for the Corridor-Wide Surveillance System. This recommendation is based on results, feedback, and analysis from the questionnaires and from Study Team's judgment. In addition to the ranking of goals and objectives that was performed in Section 2.2, effort was made on identifying discrepancies in the results from the questionnaire. In particular, emphasis was placed on identifying high priority objectives associating with low priority goals (identified in bold below); and vice versa, identifying low priority objectives (underlined below) corresponding to high priority goals (Table 2.9).

Table 2-9. Recommended Goals/Objectives for the Corridor-wide* Surveillance *System

Candidate Goals	Rank	CandIdate Objectives
Enhance traffic incident management	1	1. Provide data for automated traffic incident detection 2. Provide information for coordinated incident responses 3. Verify traffic incident reports 4. Detect disabled vehicles and assistance requests 5. Assess the severity of traffic incidents 6. Provide continuous tracking of HAZMAT carriers
Enhance real-time traffic control operations	2	1. Support real-time, traffic adaptive control 2. Enhance HOV control & operations 3. Accommodate priority vehicles 4. Facilitate reversible-lane operations 5. Improve ramp metering 6. Support congestion pricing 7. Accommodate variable speed limit determination
Enhance traffic management during snow storms and other emergencies	2	1. Support adaptive control 2. Support snow removal scheduling & operations
Improve multi-modal and inter-modal transportation operations	4	1. Provide traveler security surveillance at transit stops and stations 2. Provide link travel times for transit time of arrival estimates 3. Track transit vehicle location and schedule adherence 4. Provide park-and-ride lot status 5. Provide transit vehicle tracks as probe data 6. Provide passenger loading estimates
Support Traveler Information Services	5	1. Provide traffic conditions information (e.g., congestion, incident) 2. Provide roadway conditions information (e.g., closure, snow/ice) 3. Provide Inter-urban transit information 4. Provide urban transit information 5. Provide parking Information
Enhance the transportation systems planning database	6	1. Provide incident data (location, type, severity) 2. Provide traffic count data 3. Provide delay data 4. Provide VMT data 5. Provide traffic composition data 6. Provide vehicle O-D data
Facilitate Travel Demand Management (TDM) strategy implementation	7	1. Identify traffic congestion locations and levels 2. Characterize traffic demand levels (e.g., V/C vs. time of day) 3. Monitor air quality
Support traffic law and regulation enforcement	8	1. Provide weight measurements 2. Provide vehicle height and width measurements 3. Determine vehicle occupancy (for HOV) 4. Provide speed measurements

The survey results indicate that none of the candidate goals and objectives was rejected by the survey respondents. Even the low-ranked goals and objectives received moderate score. For example, the goal to enhance traffic incident management is ranked number 1 with a score of 3.88 (out of 4.0), while the lowest ranked goal (to support traffic law and regulation enforcement) still received a reasonable score of 2.8. Similar observations were made about the objectives. The highest and lowest scores for objectives are 3.76 and 2.66, respectively, indicating the Coalition's desirability of all the objectives for the surveillance system. These results also indicate that the goals and objectives are reasonable to the survey respondents and also that a consensus on the set of goals and objectives is achieved. Therefore, all the goal and objectives are recommended for adoption by the Coalition.

In addition, the ranked goals and objectives should be used as a basis for planning future implementation of the surveillance system in the Corridor, because they seem reasonable and consistent with the Coalition's vision. One of the key elements of this vision is to enhance incident and congestion management capabilities of Coalition's member agencies. The survey results also revealed that the highest-priority goal is to support incident management and the top-priority objectives are those that have strong relationship to this goal.

The relative importance of the goals also provides a rational approach for system implementation. Since, the surveillance needs for the above eight goals are highly overlapping in many cases, the surveillance infrastructure necessary to support incident management will, in turn, support many other goals and objectives, fully or partially. For example, the surveillance information gathered for incident management can also fulfill the information needs of the traveler information services. In summary, the Study Team's recommendation is to use the goals and objectives listed in Table 2-9 as a basis for developing the Corridor-wide surveillance system's requirements (in Chapter 5) and conceptual system design (in Chapter 6). Also, the relative ranking of the goals and objectives should be used in the development of the surveillance system deployment strategy (in Chapter 8).

CHAPTER 3
SYSTEM INVENTORY

3.1 INTRODUCTION

A survey was conducted to gather information on the existing surveillance system in the I-95 Corridor. This chapter summarizes the results of this survey. The purpose of the survey is to identify and understand the types and scope of surveillance systems already deployed, or under development, by each of the Coalition agencies and other selected organizations. The survey objectives, therefore, include the following:

- Conduct a survey among the Coalition members to determine their existing and planned surveillance systems.
- Understand surveillance information needs, use, and geographical coverage of Coalition member agencies.
- Identify surveillance gaps along the Corridor and, if possible, correlate to congested areas.
- Identify commonalties of existing systems.
- Solicit input from transit and other modal agencies for integration of their data with the Corridor-wide surveillance system.

3.1.1 Survey Approach

The survey was conducted according to the following four steps:

a. Review surveillance system technologies. This review formed a basis to understand the current state-of-the-art and state-of-the-practice of surveillance systems. The results of the review were incorporated into the survey questionnaire.

b. Conduct an inventory of existing surveillance systems in the Corridor using a questionnaire survey and interviews with Coalition members.

c. Supplement the survey data with site visits and literature review.

d. Summarize the data gathered from steps b. and c. to identify surveillance gaps, compare the cost and effectiveness among existing systems, and assess the suitability of existing systems to support the surveillance scope of the Corridor Coalition.

3.1.2 Chapter Organization

This chapter is organized to follow the logical flow of steps a. through d. of paragraph 3.1.1. Section 3.2 provides a summary of the surveillance literature review. Section 3.3 presents the approach to and the results of the questionnaire survey. Section 3.4 provides a summary of the findings from site visits. Section 3.5 describes the findings from reviewing Corridor-related documents. Section 3.6 identifies surveillance gaps. Section 3.7 presents the results of the cost effectiveness comparison from the survey data. Section 3.8 presents the results of the suitability analysis.

3.2 SURVEILLANCE TECHNOLOGY REVIEW

This surveillance technology review covers traffic surveillance systems and environmental sensing systems. It provides background information to understand various technologies that are currently in use by Coalition member agencies. The results of this review provide a starting point for the surveillance technology assessment (Chapter 4).

3.2.1 Traffic Detection Systems

Traffic detection systems may be categorized as point detection and wide-area surveillance. The following paragraphs briefly describe each detection category.

3.2.1.1 Point Detection

Common point detection technologies [for example, Cimento, 1980; Barker, 1970; Kell et al, 1990] encompass magnetic field sensor, radar detectors of all wavelengths including microwave, optical sensors such as laser and infrared, and acoustic detectors including sonic and ultrasonic.

Magnetic field sensors rely on sensing the change of a magnetic field, either induced by an electric current or the earth's ambient flux, when a vehicle passes over the device. Magnetic field sensors include inductive loop detector, magnetometer, and magnetic detector.

Inductive Loop

An inductive loop detector [Kell et al, 1990] consists of a wire loop laid in the road and an evaluation unit. An AC current, usually sinusoidal, in the frequency range from approximately 10 KHz to 200 KHz, flows through the wire loop producing an alternating magnetic field in the loop area. When a vehicle enters the loop area, the alternating magnetic field produces eddy currents in the vehicle's metal parts, causing an attenuation in the alternating magnetic field with the effect of dropping the loop's inductance and increasing its magnetic loss resistance. This change in inductance is detected by the evaluation unit to indicate sequence of presence and absence of a vehicle passage.

Inductive loops can be installed in a single loop configuration or by pairs. A single loop configuration provides vehicle passage, presence, count, and occupancy data. Vehicle speed may also be measured using a single loop but with poor accuracy. The two loop configuration provides more accurate speed measurements. The two loops are used as "speed traps" to measure the time for a vehicle traversing the distance between two loops. This time measurement combined with the known distance between the two loops determine vehicle speed.

Passive Magnetic

Passive magnetic detectors do not create a magnetic field around them and operate on the basis of detecting a change in the lines of flux from the earth's magnetic field [Kell et al, 1990]. When a vehicle nears or passes over a passive magnetic detector, the constant lines of flux passing through its coil are deflected by the vehicle, causing an induced voltage in the coil. A high-gain amplifier enables this voltage to operate a relay, triggering a vehicle detection to the controller.

Passive magnetic detectors are not suitable for detecting vehicle presence since they require some minimum vehicle speed of 3 to 5 mph for detection. They are also responsive to flux changes over a large area, covering up to three traffic lanes.

Magnetometer

Magnetometer detectors operate by sensing a change in the vertical component of the earth's magnetic field caused by the presence or passage of a vehicle over a magnetic probe embedded in the roadway pavement [Kell et al, 1990]. A voltage change is sensed when a vehicle is situated over the probe, whether or not said vehicle is in motion. A magnetometer may be thought of as "active" magnetic detectors.

Magnetometers are often used where pavement trauma is of concern and where inductive loops are disrupted by the steel support structure or where the existing structure, such as a bridge deck, can weaken.

The Self-Powered Vehicle Detector (SPVD) [FHWA, 1985] is a magnetometer detector with a self-contained battery and transmitter. The transmitter broadcasts passage or presence information of a vehicle to a receiver located remotely in a controller cabinet, eliminating the need for lead-in cables. SPVDs have applications where temporary installations are needed or where they can be easily mounted under bridges or viaducts.

Radar

A radar (RAdio Detection And Ranging) detector consists of a transmitter, a receiver, a transmitting and receiving antenna, and an evaluation unit (or signal processor). The radar antenna emits electromagnetic waves and the reflected waves (either off the background or a vehicle within the antenna's field of view) are received and processed. Most radars employ Radio Frequencies (RF) lying somewhere between a few hundred megahertz (MHz) and 100,000 MHz. Radars are often identified by the characteristic RF wavelength as well. Commercially available radars for traffic detection operate in frequency bands near 10.5 GHz (X-band), 24.0 GHz (K-band), and 34.0 GHz (Ka-band) because of Federal Communications Commission (FCC) regulations. All of these frequency bands are designated as microwave, thus traffic detection radars are sometimes known as microwave radars.

Microwave radars used in traffic applications are of two types [Hughes Aircraft Company, May 1994]. The first transmits a continuous wave of electromagnetic energy. It measures the speed of vehicles in its field of view using the Doppler principle. The second type of radar transmits a saw-tooth waveform, also called frequency modulated continuous wave (FMCW), in which the transmitted frequency is constantly changing with respect to time. The FMCW radar functions as a presence detector. It can also measure vehicle speed when its field of view or footprint in the direction of vehicle travel is divided into range bins.

Laser

A laser sensor has a laser emitter and receiver pair, operating in the 1.5 to 1.9 micrometer wavelength [Rockwell International Corporation, February 1994]. The sensor may be mounted directly over the traffic lane to emit a laser beam onto the road surface. Vehicle presence is detected using range finding techniques. As a vehicle passing through the detection zone, the change in the laser reflection is measured by the receiver to declare detection. Laser sensors typically have a range of over 150 feet, making sidefire mounting possible.

Laser systems are currently in the experimental phase and not likely to become a deployable product in the near future. Furthermore, the potential health hazard of this technology (either perceived or actual) makes it somewhat unattractive.

Infrared (IR)

Infrared detection devices currently marketed consist of both active and passive models [Hughes Aircraft Company, May 1994]. In the active system, the device illuminates the roadway with lower power IR energy. As vehicles traveling through its detection zone, the system focuses the reflected IR energy onto a detector matrix, mounted on the focal plane of the optics. The system's processor analyzes the received signals to determine the presence of a vehicle. Changes in received signal levels caused by environmental effects, such as weather and shadows, can be compensated for through signal processing. Infrared sensors are available for overhead mounting to view approaching or departing traffic, and sidefire mounting.

Any warm subject emits energy in the IR range. The frequency and intensity of the emitted IR radiation depend on a number of influencing parameters. Passive IR detectors consist of an infrared sensor for receiving IR radiation, coupled with an amplifier and an evaluation unit.

Since a passive IR detector only detects changes in the intensity of the received IR radiation, the target vehicle must move through the detector's field of view at some minimum speed to be detected. Thus, passive IR detectors are not suitable for counting vehicles and do not detect vehicles at rest.

Sonic

Sound waves are longitudinal mechanical waves propagated in solids, liquids, or gases. There is a wide range of frequencies within which longitudinal waves can be generated, and detectors that sense sound waves through any medium are denoted acoustic detectors. The band from 20 Hz to 20 KHz is referred to as the *audible* or *sonic* range, since humans can generally hear frequencies in that interval. Longitudinal mechanical waves whose frequency exceeds the audible range are denoted *ultrasonic* waves.

+ Ultrasonic Detectors. Ultrasonic detectors operate in a frequency range from around 30 KHz to 100 KHz and consist of an ultrasonic transmitter and receiver, and an evaluation unit. The transmitter and receiver are often packaged as an ultrasonic transducer. The ultrasonic transducer emits ultrasonic waves that are reflected off a vehicle in the detector's field of view, or off the background, and then received by the transducer. Two methods of detection are used: either a pulse mode or a Doppler mode.

  When an ultrasonic detector is operating in the pulse mode, the presence of a vehicle in the field of view causes a shorter elapsed time between transmission and reception of an ultrasonic signal than would otherwise occur. Some degree of classification is available if the detector is mounted directly over the roadway because the round-trip time from transmitting to receiving indirectly measures the height of the vehicle.

+ An ultrasonic detector Doppler mode is similar to a Doppler mode for radar; an oncoming vehicle will cause the reflected ultrasonic signal to increase in frequency by a predictable function of the vehicle's velocity, the observation geometry, and the ultrasonic detector's operating frequency. Similarly, as a vehicle recedes from the detector, the reflected frequency decreases. The frequency shift of the received ultrasonic signal is used to detect signals and occasionally used to measure their velocity.

The speed of sound in air depends mainly on the ambient temperature, but barometric pressure fluctuations can also influence the accuracy of ultrasonic detectors. Measurement accuracy can be derived from data relating the speed of sound to atmospheric temperature and pressure and be able to compensate for known variations accordingly. There is anecdotal evidence that ultrasonic sensors are susceptible to wind gusts, as well as environments with high ambient noise. Except in extreme conditions, these error sources can be moderated.

+ Passive Acoustic Detector Arrays. A passive acoustic detector is composed of microphones that receive acoustic energy from vehicular traffic (e.g., moving parts of the vehicle, and the interaction between the tires and the pavement). The microphones provide spatial directivity from which sound energy is continuously received and processed, rejecting or attenuating that which originated from locations outside the detection zone [Hughes Aircraft Company, May 1994]. The size and shape of the detection zone are determined by the sensor aperture size, processing frequency band, and installation geometry.

  The sound energy increases as a vehicle enters the detection zone and decreases as it leaves the detection zone. Using this principle, a passive acoustic detector an provide a vehicle presence output in the form of contact closures for use in calculating traffic volume, occupancy, and average speed.

3.2.1.2 Wide-Area Detection

Video Imaging

Video cameras have provided roadway surveillance for many years. Closed-circuit television (CCTV) provides scene images to a human operator for interpretation. More advanced techniques now use video image processing to automatically analyze the scene and extract information for traffic surveillance and control.

An image processing traffic sensor system consists of a video camera, an analog-to-digital image digitizer that converts the video image to gray-level values, and an image processor to evaluate the digital images and derive relevant traffic parameters as a function of time. The camera can be mounted either overhead or on road side structures and generates a video image of the surveillance site at a 30 Hz rate. The system can provide vehicle presence, speed, lane occupancy, lane flow rate, and classification information. Often, the image processing sensor system is denoted the Wide Area Detection System, or WADS [Inigo, 1989; FHWA, 1990]. The accuracy of video image processing systems depends on the mounting location and the environmental conditions. In low-light or night conditions, headlights are generally used to detect vehicles. In such cases, the rear end of vehicles cannot be distinctively detected, thus effecting the accuracy of vehicle lengths and classifications [Rockwell International Corporation, February 1994].

Aerial Surveillance

Aerial surveillance has been very successful in military applications and can provide an alternative to area-wide traffic surveillance. Although many agencies in the country have used aircraft (fixed- wing and helicopter) to conduct traffic surveillance, the lack of advanced sensor and air-to-ground communications technologies limits the effectiveness of this method.

The primary advantage of aerial traffic surveillance is the area-wide picture of the traffic conditions along the roadways. In addition, with the availability of advanced wireless communications technologies, an expensive terrestrial communications network is not needed to transmit field surveillance data to traffic management centers.

With the recent defense-conversion initiatives, military sensor technologies may be available for traffic surveillance purposes. For example, technologies such as airborne radar, infrared imaging system, radar/forward-looking IR, video data link, and multi-sensor operator work station are being packaged into light-weight aircraft for border surveillance, forestry patrol, fisheries patrol, and law enforcement. Such an aircraft can offer a mission endurance of seven or more hours. Similar air-to-ground sensor and communication technologies may be installed on an airship or other airborne vehicles to extend the mission endurance.

Vehicle Probes

Vehicle probes offer real-time traffic information over a section of the roadway as opposed to “localized” data offered by point detection devices. Two commonly used methods are the acquisition of Automated Vehicle Identification (AVI) data and Automated Vehicle Location (AVL) data. AVI systems have been used in Electronic Toll and Traffic Management (ETTM) functions and electronic commercial vehicle clearance operations. Vehicles may be identified using signals emitting from an onboard transponder and recorded by a roadside reader. A variant on this concept is the wider range radio location of onboard equipment by an installed radio infrastructure (e.g., the cellular telephone network or those of various fleet management and theft detection services). The ability to identify a particular vehicle allows link travel times and average highway operating speeds to be computed for specific roadway segments. Techniques for AVI that do not require onboard equipment (e.g., license plate recognition) are particularly suited to early deployment scenarios because a large percentage of vehicles are not AVI equipped.

AVL technologies have been used primarily for vehicle tracking (e.g., buses and commercial trucks). The rate at which vehicle locations are reported depends on the applications, ranging from once per second to a few minutes. Similar to the AVI technologies, AVL systems can provide location-specific, average highway operating speeds. Common AVL techniques include the use of the Global Positioning System (GPS), sign post, and cellular telephone infrastructure. Other AVL technologies such as one using LORAN-C (for maritime navigation) have been tried but without satisfactory location accuracy.

3.2.1.3 Comparison of Performance

Although there are many different vehicle detection technologies, they all have their inherent advantages and disadvantages. Table 3-1 summarizes the capabilities as well as advantages and disadvantages of a number of traffic sensors discussed earlier.

3.2.2 Environmental Sensors

A number of sensors are available to measure the various environmental conditions. These include both the condition of the pavement and the atmosphere. Pavement sensors provide surface temperature and conditions (e.g., ice); while atmospheric sensors provide information on temperature, air quality, wind speed, visibility, etc. Three major categories of information are significant for traffic management:

+ Road condition information is collected by surface sensors and is important to traffic safety. The road condition data (such as wet or icy pavement) can be used to provide advisory information to motorists.

Table 3-1. Traffic Sensor Technology Characteristics

Technology	Measuring Capabilities	Advantages	Disadvantages
Inductive Loop	Presence Count Speed Occupancy Queue Length	- Proven technology - All weather, day/night operation - Size & shape of detection zone shaped by loop geometry - Capable of measuring all traffic parameters	- Lane closure required for installation and maintenance - Susceptible to damage due to thermal coefficient of expansion mismatch - Cutting of pavement reduces life span of road
Microwave	Count Speed	- Above ground mounting - Only a single head needed to measure velocity	- Unable to detect motionless vehicles - Precision setup required - Potential health hazard - Deployment number limited
Laser/Infrared (active)	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Accurate vehicle length measurement	- Susceptible to spectral interference - Potential health hazard - Not proven technology in traffic applications
Pulsed Sonic (active)	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Can be used at locations with irregular surfaces - Slightly improved speed - Measurements than pulsed sonic	- Non directional - Conical beam pattern provides inaccurate measurements - Accuracies degrade under congested traffic
Continuous Sonic (active)	Count Speed	- Above ground mounting - Can be used at locations with irregular surfaces - Slightly improved speed measurements than pulsed sonic	- Sensitive to environment conditions - Cannot detect motionless vehicles
Radar	Count Speed	- Above ground mounting - Not effected by electromagnetic interference	- Requires FCC license to operate - Does not measure presence or occupancy - Precision setup required - Potential health hazard - Currently in field test
Passive Sonic	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Potentially accurate vehicle classification	- Cannot detect stalled vehicles - Not a proven technology - Susceptible to environmental interference
Passive Infrared-Lane Coverage	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Operates in snow, rain, fog - Can provide all traffic parameters	- Currently under test - Potential high O&M cost - Detailed setup required
Passive Infrared-Area Coverage	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Operates in snow, rain, fog - Can provide all traffic parameters	- No current traffic applications - Potential high O&M cost - Detailed setup required
Magnetic	Presence Count Speed Occupancy Queue Length	- Proven technology - Not effected by noise from direct current power lines - Can be mounted under bridges without cutting pavement	- Requires lane closure during installation and maintenance - Multiple units to measure velocity - Potential multiple triggers on single vehicle
Machine Vision	Presence Count Speed Occupancy Queue Length	- Above ground mounting - Provides all traffic data - Does not depend on pavement condition - Technology rapidly improving	- Detailed setup required - Units currently being geld tested - Long term operation unknown

+ Visibility data is crucial to traffic safety. Necessary warnings can be provided to motorists based on visibility conditions.

+ Air quality data is useful to traffic and travel demand management, especially in ozone non-attainment areas.

A description of some of the leading environmental sensor technologies follows.

3.2.2.1 Weather Sensors

Surface Condition Analvzer (SCAN)

This system provides pavement surface condition information and transmits the real-time data to a central computer. SCAN data include:

+ Surface temperature.
+ Surface conditions (dry/wet/icy).
+ Presence of chemicals on the roadway.

Handar[1]

This system measures both visibility and atmospheric conditions. It provides the following information:

+ Visibility.
+ Air temperature.
+ Humidity.
+ Barometric pressure.
+ Wind speed and direction.

3.2.2.2 Vehicle Emissions Sensors

Lidar (Light Detection and Ranging)

[1] Handar TM is a trademark of Environmental Measurement Solutions.

This system uses laser beams to scan an area to determine the concentration of particles in the atmosphere. It collects real-time information on visibility and air pollution and transmits the data to a central computer. It can make measurements over a distance of up to 20 miles. The Lidar system provides visibility and particle concentration information (e.g., snow, fog, sand, carbon monoxide).

3.3 SYSTEM INVENTORY: QUESTIONNAIRE SURVEY

An inventory of the existing surveillance systems in the I-95 Corridor was necessary to provide information for developing the requirements and conceptual design of the Corridor-wide surveillance system. A survey was conducted for this purpose. This section provides a summary of the survey effort, including a description of the approach and an analysis of the results.

3.3.1 Survey Design

3.3.1.1 Target Audience

The target audience for the survey includes both public and private sectors in the Corridor. Since this survey was conducted in conjunction with the System Goals and Objectives survey (Chapter 2), the same Coalition member agencies and private organizations were contacted. The points-of-contact for the public sector and private organizations are provided in Appendices A and B, respectively.

In addition to the questionnaire survey and telephone interviews, three public agency operations centers were visited for additional data gathering. The results of these visits are reported in Section 3.4 of this paper. Appendix F contains a sample survey questionnaire.

3.3.1.2 Questionnaire Development

The objective of the Existing Systems Inventory Survey is to establish a database for existing and planned surveillance systems within the Corridor. This database was intended for use in comparing the cost-effectiveness of various sensor systems and determining those that may be suitable for a corridor-wide application.

Existing and Planned Sensor Systems

The existing and planned surveillance system questionnaire contains the following information requests:

+ Highway name.
+ Existing or planned system.
+ Geographic location.
+ Length (miles).
+ Facility type (freeway or arterial).
+ Sensor type.
+ Quantity.
+ Polling rate.
+ Surveillance data type.
+ Communication medium (from field to central computer).
+ Purpose of the sensor.
+ Fulfillment of purpose with the existing sensor.

This information helps to determine the extent to which surveillance systems are used; identify areas which have operating surveillance systems (and therefore gaps in coverage); determine how the system is implemented and operated: and determine technology compatibility throughout the Corridor.

Improvement Needs

Two areas of improvement needs were requested to provide:

- Additional surveillance information needs.

- Additional surveillance coverage needs.

The purpose of the former was to identify the type of information that the agencies would like to have to more effectively manage traffic and incidents (e.g., queue length, incident severity assessment, etc.). The purpose of the latter is to understand other local needs that are not covered by existing or planned systems.

System Cost and Performance

The purpose of requesting existing system cost and performance information is to develop a cost-effectiveness comparison for the systems currently in use. The following cost and performance information was requested:

- Sensor type.

- Cost, both in capital and yearly operation and maintenance.

- Satisfaction with data accuracy.

- Rate of failure and maintenance needs.

- Frequency of maintenance and preventative maintenance.

- Performance sensitivity to any external factors.

- Rating the level of ease of installation, maintenance, and relocation of sensors.

- Comments or remarks.

Within the scope of this project, it would be very difficult to properly conduct a quantitative cost-effectiveness analysis. Therefore, the approach taken was to gather subjective ratings on the system performance.

Human Surveillance

Police patrol, freeway service patrol, and motorist call-in are typical human surveillance methods used by many transportation agencies. The type of information collected and the level of effectiveness of these methods were requested.

Transit Surveillance

Currently, many I-95 Corridor Coalition agencies operate or interface with transit systems such as bus, subway, light rail, or ferry systems. These agencies may use AVL technology for vehicle tracking and fleet management. They may also have automatic passenger counters and fare collection devices onboard transit vehicles to monitor ridership. This information is needed to determine the surveillance requirements to support intermodal goals and compliance with ISTEA Management Systems.

3.3.2 Analysis of Survey Results

The survey questionnaires were sent to 37 Coalition member agencies. However, only 26 agencies - representing transportation authorities, and state and local DOTs responsible for deployment and operation of surveillance systems - could respond to the questionnaire. Out of the 26 potential agencies, 21 responded, representing a response rate of 81 percent. It should also be noted that not all 21 survey returns provided all the information requested. This is evident by the sample size shown in the statistics presented in this section. Appendix G contains a summary of survey data for existing and planned surveillance systems for all responding agencies. The existing and planned sensor information were plotted on an AutoCAD drawing (see Figure 3-1).

While the detailed analysis of the survey data are provided in the following subsections, Table 3-2 presents a very high-level picture of the existing and planned surveillance capabilities. In the table, E and P denote existing and planned systems respectively. The table reveals that most of the agencies have inductive loops and CCTVs in their surveillance systems. It appears that the use of loop detectors was under-reported in the survey responses.

Table 3-2. Existing and Planned Sensor Capabilities of Responding Agencies

Agency	Ind. Loop	Mageneto-meter	Radar	Sonic, Pulsed	IR	Video Image Process.	CCTV	WIM - Bending Plate	WIM – Deep Pit	WIM – Piezo-electric	AVI/ETTM	AVL	SCAN	Other Environ
Conn. DOT	E-P				P		E-P			E				P
D.C. DPW							P	P			P	P	E	P
Del. DOT							P							
Maine TA											P			
MDSHA	E-P		P				E-P						E-P	
MDTA	E-P		P			P	E-P						P	
NH DOT	E													
NJHA	P		P			P	P							E
NJTA	E-P	E		E		E	P							P
NY&NJ Port Authority			E-P			E	E							
NYC DOT	E													
NYS DOT	E						E-P							
NYS Thruway Auth							P							
Penn DOT	P						E-P							
PTC	E						E		E					E
RI DOT	E													
VDOT	E-P						E-P			E-P				

a. E denotes existing, P denotes planned surveillance system

3.3.2.1 Existing Surveillance Systems

Sensor Types

The survey results showed the following 10 different types of sensors currently used in the Corridor:

1. Inductive Loop.

2. Magnetometer.

3. Radar.

4. Sonic, Pulsed.

5. Video Image Processing.

6. CCTV.

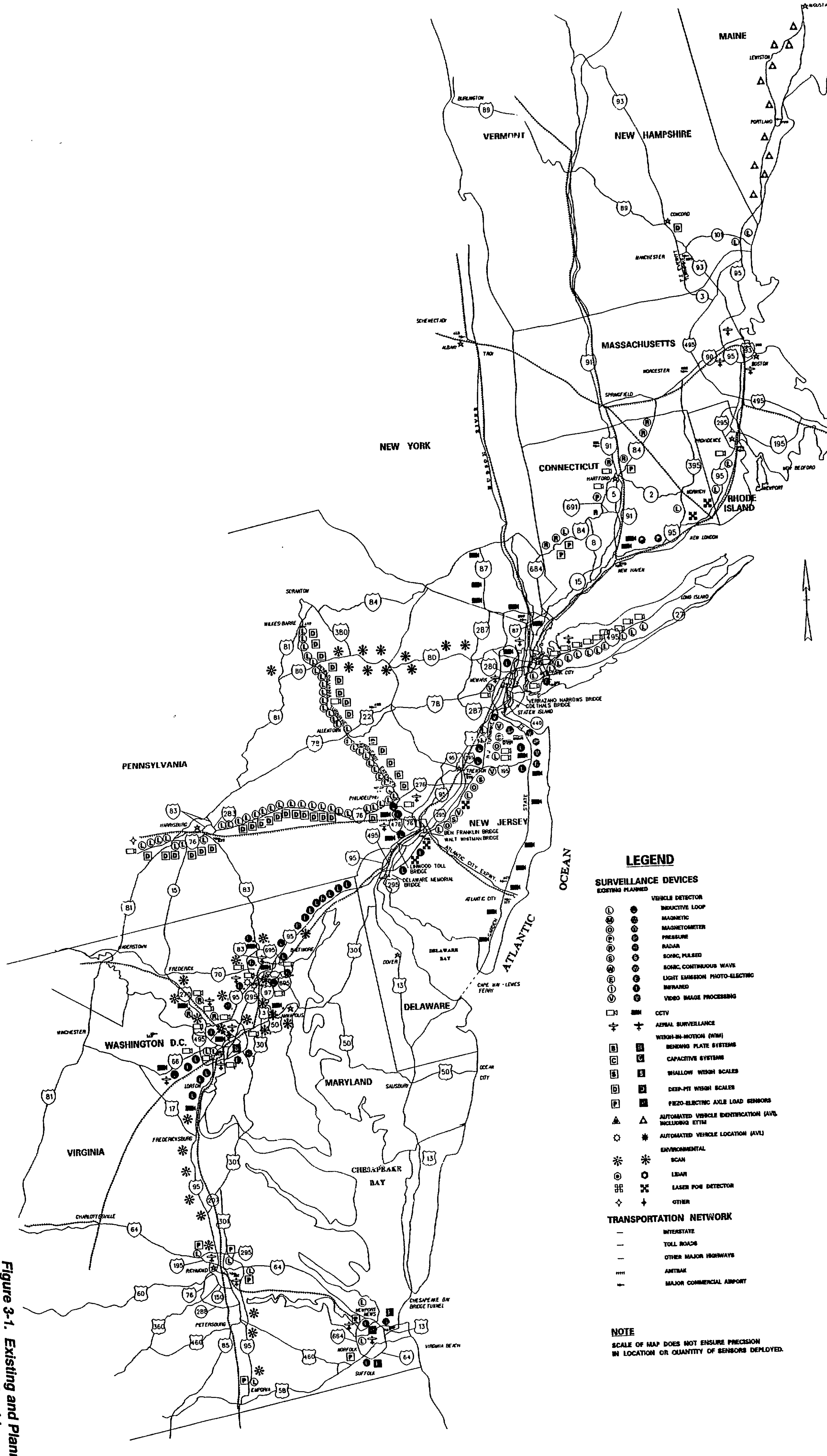

Figure 3-1. Existing and Planned Sens in I-95 Corridor.

7. WIM - Deep-Pit Scale.

8. WIM - Piezo-Electric.

9. SCAN.

10. Other Environmental.

Sixty-four (64) percent of agencies use. inductive loop detectors (refer to Figure 3-2) which is unreasonably low and seems to be under-reported. The next widely used sensor is CCTV with 50 percent of the agencies. These results are consistent with those obtained in the Goals and Objectives Survey, showing the agencies' preferences to continue using loop detectors, CCTV, and radar, in that order, in the future. The use of AVI and ETTM technologies for surveillance should be added to the list because they are currently used by TRANSCOM.

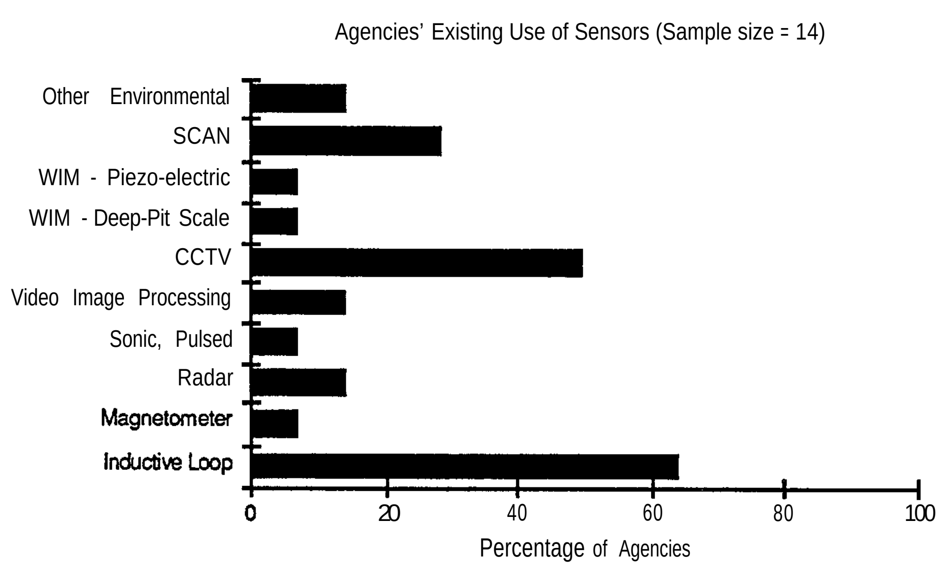

Figure 3-2. Distribution of Responding Agencies Using Each Sensor Type

Sensor Use

Existing sensors are used predominantly for incident detection and verification (75 percent of agencies). Other uses include volume and speed monitoring, weight measurements, weather and environmental monitoring, and toll collection.For incident detection, 67 percent of the agencies use CCTV and 56 percent use inductive loops (refer to Figure 3-3).

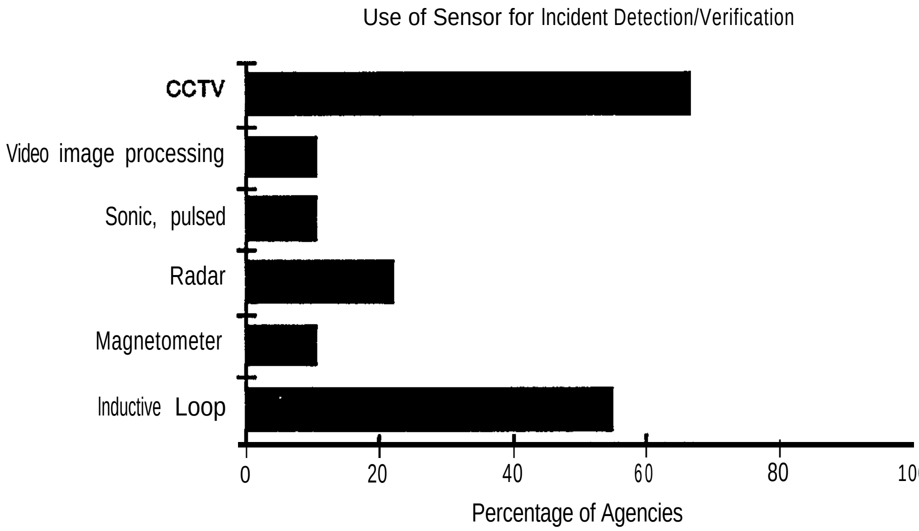

Figure 3-3. Existing Incident Detection Sensor Use

Inductive loops are also the predominant sensor to measure both vehicle speed and classification (see Table 3-3).

Table 3-3. Existing Sensors for Determination of Speed and Classification

Data Type	Sensor	Number of Reported Systems
Speed	Inductive Loop	12
	Radar	2
	Piezo-electric WIM	1
Classification	Inductive Loop	7
	Inductive loop and Deep-pit weigh scale WIM	2
	Radar	1

Polling Rates

Polling rates for sensor types were examined to determine commonalties among the Coalition members. The polling rate for existing inductive loops ranges between 0.25 seconds to 60 seconds (see Table 3-4). For environmental and weather sensors, the polling rate varies between 30 seconds and 15 minutes. Video image processing sensors continuously provide image data. One agency reported a rate of 13 frames/sec for the CCTV image data polling.

Table 3-4. Polling Rates of Existing Inductive Loop Sensors

Polling Rate, sec.	Number of Sensor Systems Reported
0.25	3
0.65	1
2.0	1
30.0	3
60.0	1

Communication Methods

Forty-one data communication samples from existing sensors were provided by the survey respondents. The existing communication methods fall into seven categories: coaxial cable, copper, fiberoptic, microwave, T1, telephone line, and manual (for recording data at traffic count stations) as shown in Figure 3-4. The most widely used method is the telephone line (44 percent of all cases), followed by coaxial cables (22 percent).

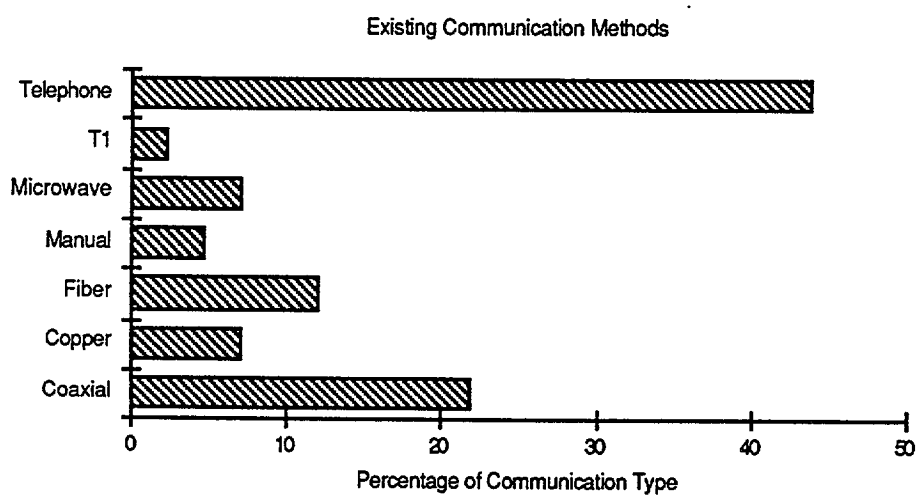

Figure 3-4. Existing Communication Methods

Fulfillment of Purposes

Subjective ratings (High, Medium, Low, and Unfulfilled) were used to measure the ability of the sensors to fulfill their purposes. To aggregate the responses, numerical values of 0, 1, 2, and 3 were assigned to the Unfulfilled, Low, Medium, and High ratings, respectively. Table 3-5 shows the average value of the responses for all sensors. No ratings of Low or Unfulfilled were given in the survey. The rating sample sizes were larger for inductive loops, CCTV, and piezo-electric WIM, compared to those for other sensors.For the ones with small sample sizes, their fulfillment of purposes cannot be concluded. Inductive loops and CCTV were both rated satisfactorily while piezo-electric WIM was rated with the highest possible score.

Table 3-5. Rating for Sensors

Sensor Type	High	Medium	Low	None	Sample Size	Grade[a]
Inductive Loop	14	7	0	0	21	2.67
Magnetometer[b]	1	0	0	0	1	3.0
Radar[b]	0	3	0	0	3	2.0
Pressure[b]	1	0	0	0	1	3.0
Infrared[b]	1	0	0	0	1	3.0
Video Image Processing[b]	2	0	0	0	2	3.0
CCTV	11	7	1	0	19	2.53
WIM - Bending Plate[b]	0	2	0	0	2	2.0
WIM - Deep-pit Weigh Scale[b]	0	2	0	0	2	2.0
WIM - Piezo-electric	8	0	0	0	8	3.0
Environmental -SCAN[b]	1	1	0	0	2	2.50
Other Environmental[b]	3	1	0	0	4	2.75

a Scale: 0 = Unfulfilled; 3 = High
b Sample size too small.

3.3.2.2 Planned Surveillance Systems

The sample size of the survey returns for planned surveillance systems had two fewer samples compared to that of the existing systems (12 versus 14). Thus, any differences between the two cases should be interpreted as relative.

The results showed 11 different types of sensors considered for future implementation (see Table 3-6). Eight planned sensor types are the same as those currently in use. Note that three existing sensor types (magnetometers, pulsed sonic, and deep-pit scale WIM) are not considered for future implementation probably because of their unsatisfactory performance.

Table 3-6. Comparison of Planned Versus Existing Sensors

Planned Sensors: Same as Existing	Planned Sensors: Different from Existing	Existing Sensors Excluded
Inductive Loop	Infrared	Magnetometer
Radar	WIM - Bending Plate	Sonic, Pulsed
Video Image Processing	AVL	WIM - Deep-Pit Scale
CCTV		
WIM - Piezo-electric		
AVI & ETTM		
SCAN		
Other Environmental		

Eighty-three (83) percent of the responding agencies plan to deploy CCTV systems and 50 percent plan to install inductive loop detectors (refer to Figure 3-5). The use of radar detectors seems to gain more acceptance (42 percent planned as opposed to 14 percent existing).

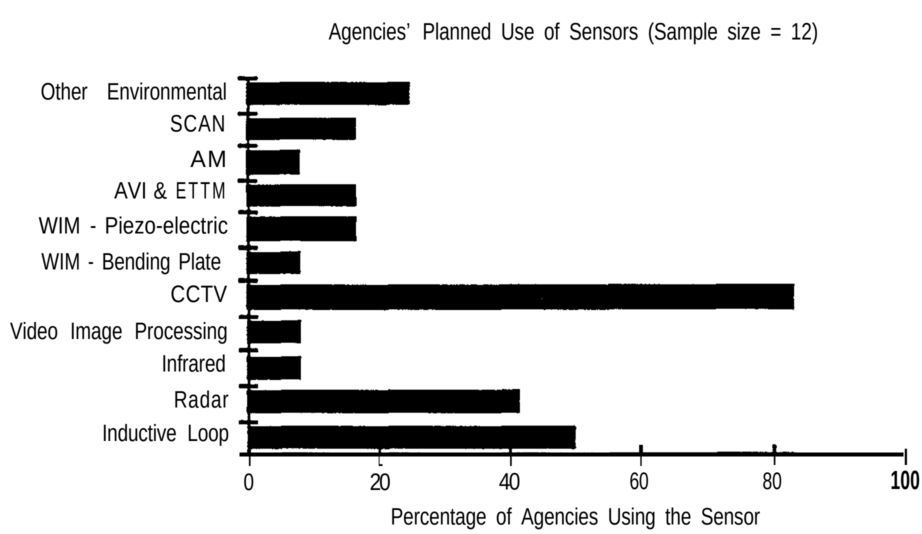

Figure 3-5. Distribution of Agencies Planning to Use Each Sensor Type

<u>Purpose of Planned Sensor System</u>

Incident detection remained to be the primary purpose of future sensor deployment (10 out of 11 agencies reported). Other purposes include height measurement, CO detection, weight measurement, and toll collection. For incident detection, 80 percent of agencies plan to use CCTV, 50 percent use inductive loops, and 40 percent use radars (refer to Figure 3-6).

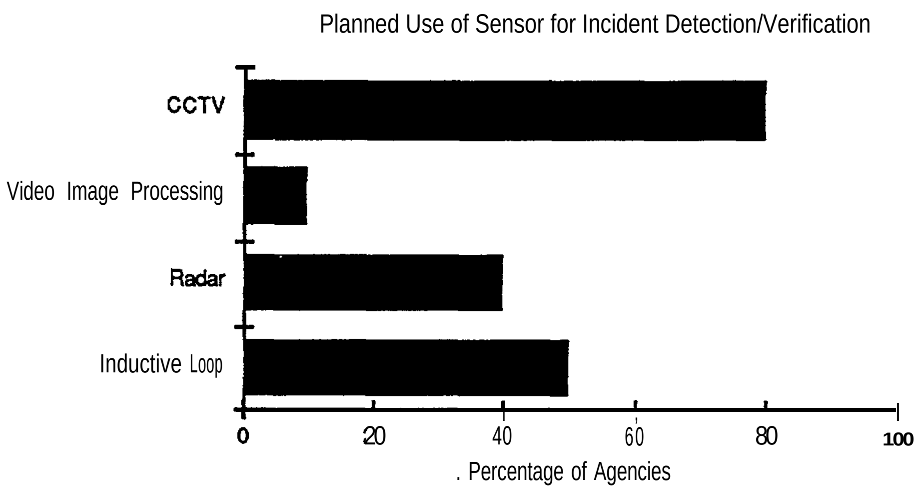

Figure 3-6. Planned Incident Detection Sensor Use

<u>Planned Sensor Types for Determining Speed and Classification</u>

Table 3-7 indicates that inductive loops continue to be used to determine both vehicle speed and classification, though the future use of other sensor types also emerges.

Table 3-7. Planned Sensors for Determination of Speed and Classification

Data Type	Sensor	No. of Reported Systems
Speed	Inductive Loop	6
	Radar	4
	Video Image Processing	1
	Inductive Loop and Piezo-electric WIM	3
Classification	Inductive Loop	3
	Radar	1
	Bending Plate WIM	2
	AVI and ETTM	2

Polling Rate for Planned Sensors

The polling rates for a planned traffic sensor were reported to be either 0.25 seconds or 60 seconds, with a shift towards 60 seconds. The polling rate of one planned environmental sensor was reported as 60 seconds. Continuous polling was planned for WIM/AVL.

Planned Communication Methods

Figure 3-7 shows that fiber optics is the preferred communications medium of future surveillance systems (58 percent of planned installations). A corresponding decrease in the use of telephone lines and coaxial cables was observed.

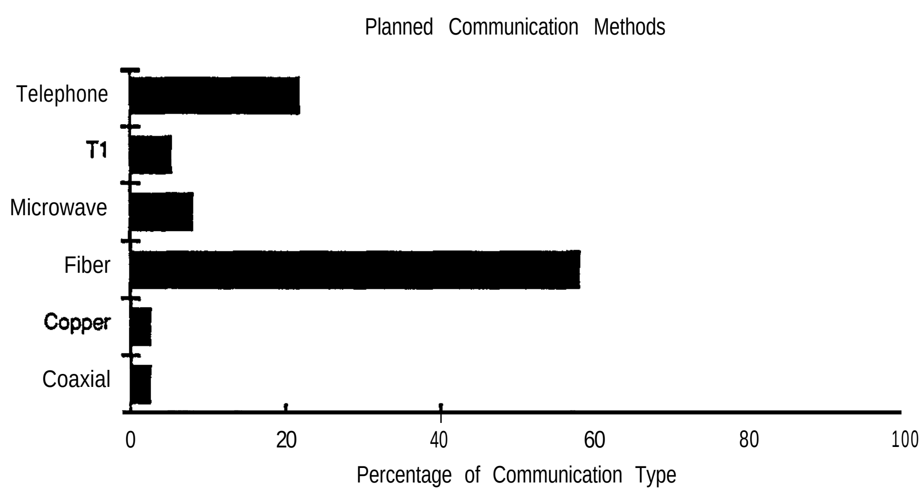

Figure 3-7. Planned Communication Methods

3.3.2.3 Desired improvements (based on survey responses)

The survey respondents were asked to identify the agency' s perceived needs for additional surveillance data and additional surveillance coverage area. Fourteen transportation agencies responded to the question by identifying their needs (see Table 3-8). Some specific areas that need surveillance coverage were identified. Specific data needs for speed, occupancy, and classification data were identified by a few agencies. Surveillance requirements for real-time traffic management, incident detection, and motorist information were also identified.

Table 3-8. Additional Surveillance information and Coverage Needs

Agency	Additional Surveillance Information Needs	Additional Surveillance Coverage Needs
O.C. DPW	Real-time Traffic Management.	Interstate system lacks surveillance.
Virginia DOT	Lack of coordinated information between freeway traffic and local arterial traffic.	
N.J. Turnpike Authority		NJ. Turnpike to Penn. Turnpike link 6 mile stretch. 8 mile extension between exit 14 and 14C to Newark Holland Tunnel.
Penn. Turnpike Commission	Speed and class information between interchanges (not just at interchanges and AVI/L).	Between interchanges.
Maryland Transportation Authority	Under development by JHK & Assoc.	Under development by JHK & Assoc.
Penn. DOT		Whole stretch of Girard Bridge to give full coverage and especially to see VMS.
Maine Turnpike Authority	Speed, occupancy, video.	Between plazas.
N.J. Highway Authority	Need to implement planned systems	
N.Y. City DOT	More sensors.	
Port Authority N.Y. & N.J.		Goethals Bridge/ Outer bridge Crossing/George Washington Bridge.
Delaware DOT	General incident detection data. Data to facilitate motorist guidance.	Expand data collection to freeways. Initiate cellular phone-in system ('77).
New York State DOT	More cameras.	Complete system on I-495 to exist 64.
New Jersey Transit	Park and Ride availability	Northeast corridor
Connecticut DOT		Additional video and sensor coverage required on some highways (including Hartford areas).

3.3.2.4 System Costs and Performance Data

The purpose for gathering the deployment cost and effectiveness data was to compare the cost-effectiveness of various sensor systems currently in use in the Corridor. Cost data included initial costs and annual operations and maintenance (O&M) costs, while system effectiveness data included subjective ratings on the sensor performance and ease of installation, maintenance, and relocation. The survey returns contained a limited number of cost-related responses. Even for those responses with cost data, the costs varied widely due to the different applications of the sensor systems. Thus, cost data from other sources were collected to supplement the survey data.

The survey's cost and performance data were available for seven sensor types, but with different sample sizes (refer to Table 3-9). A sample size of eight (the largest sample size) was obtained for inductive loop detectors, while only one was obtained for magnetometer and video image processing sensors.

Table 3-9. Sensors for Which Information is Available from the Survey

Sensor Type	Sensor Code (used In survey)	Sample Size
Inductive Loop Detector	1	8
Magnetometer	3	1
Radar	5	2
Video Image Processing	10	1
CCTV	11	5
WIM – Piezo	17	3
Weather - SCAN	20	3

Cost Information

Table 3-10 shows the average values of the initial costs as well as annual O&M costs reported in the survey. Cost items that were not provided are denoted as "N/A" in the table. The raw data have shown some variation in the cost figures for some sensor types which may be attributed to their different functionalities.

Table 3-10. Initial and Operational Cost Information

Sensor Type	Initial Cost	O&M Cost ($/Yr)
Inductive Loop Detector	$1,100	$130
Magnetometer	N/A	N/A
Radar	$25,900	N/A
Video Image Processing	N/A	N/A
CCTV	$14,400	$3,700
WIM – Piezo	$3,100	$1,000
Weather - SCAN	$50,600	$2,000

Maintenance Needs

The maintenance and preventive maintenance needs data were not available for magnetometer, and video image processing. The exact reason for the missing data is unknown. However, one might speculate that the maintenance records for video image processing sensors are not available due to their recent implementation in traffic detection.

Besides the missing data, some respondents reported maintenance and preventive maintenance of sensors on a daily basis instead of yearly. It appeared that these types of maintenance were performed for the entire system, rather than for individual sensors. In such cases, the data points were excluded in the analysis to avoid bias. Table 3-11 shows the average values of the yearly maintenance frequencies received from the survey.

Table 3-11. Annual Sensor Maintenance Frequencies

Sensor Type	Maintenance	Preventative Maintenance
Inductive Loop Detector	0.8	0.5
Magnetometer	N/A	N/A
Radar	0	0
Video Image Processing	N/A	N/A
CCTV	0.7	18.0
WIM – Piezo	0.5	0.5
Weather - SCAN	1.5	1.0

Sensor Performance Data

Subjective ratings were used to measure the satisfaction on sensor data accuracy, failure rate, and ease of installation, maintenance, and relocation. To aggregate the surveyed data, numerical values were assigned to each subjective response as shown in Table 3-12. Average ratings were computed for all performance categories as shown in Table 3-13.

The following figures present the above data in graphical form. Figure 3-8 shows that the level of satisfaction for data accuracy is the highest with weather sensors and piezo-electric WIMs. Loop detectors receive a score slightly higher than average. Figure 3-9 shows that piezo-electric WIM, video imaging sensors and loop detectors are perceived to have a medium failure rate, CCTV a low failure rate, and radar a zero-failure rate.

Table 3-12. Rating Scales for Sensor Performance Subjective Responses

Sensor Performance Measures	Subjective Response	Assigned Numerical Value
Data Accuracy Satisfaction	Unsatisfied	0
	Low	1
	Medium	2
	High	3
Rate of Failure	Unsatisfied	0
	Low	1
	Medium	2
	High	3
Ease of Installation	Very Easy	0[a]
Ease of Maintenance	Between Easy and Difficult	1 to 4[a]
Ease of Relocation	Very Difficult	5[a]

[a]Values provided by respondents.

Table 3-13. Performance Ratings of Sensors

Sensor Type	Data Accuracy Satisfaction[a]	Rate of Failure[b]	Ease of Install.[c]	Ease of Maint.[c]	Ease of Reloc.[c]	Sensitivity/Agency Remarks
Inductive Loop Detector	2.3	2.0	2.8	2.8	4.7	Sensitive to pavement condition
Magnetometer	1.0	1.0	3.0	5.0	5.0	Does not work
Radar	2.0	0	1.0	2.0	2.0	
Video Image Processing	2.0	2.0	5.0	3.0	3.0	
CCTV	2.0	1.3	3.0	1.8	4.5	Sensitive to ice, birds, dirt, weather and lighting
WIM – Piezo	2.5	2.0	3.5	3.5	4.0	
Weather	2.5	1.5	4.0	2.0	5.0	

a. On a 0-3 scale (0 for Unsatisfied, and 3 for High)
b. On a 0-3 scale (0 for Never Failed, and 3 for High)
c. On a 0-5 scale (0 for Very Easy, and 5 for Very Difficult)

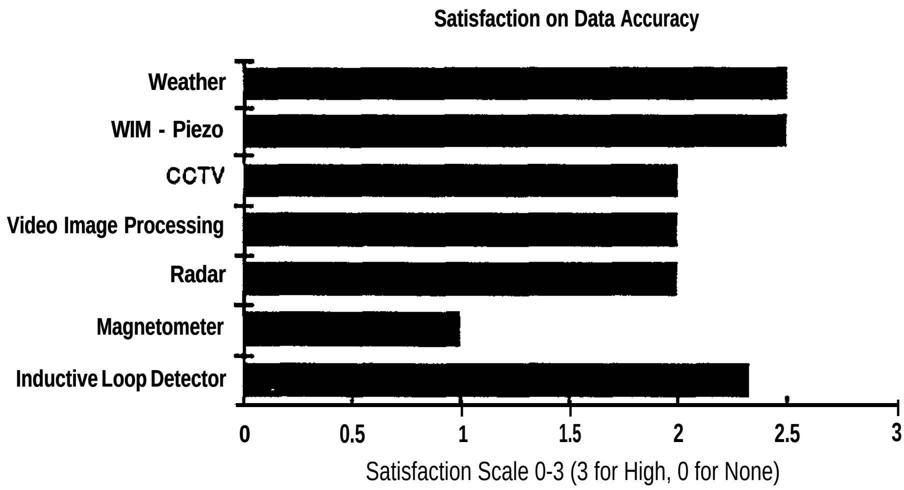

Figure 3-8. Rata Accuracy of Sensors

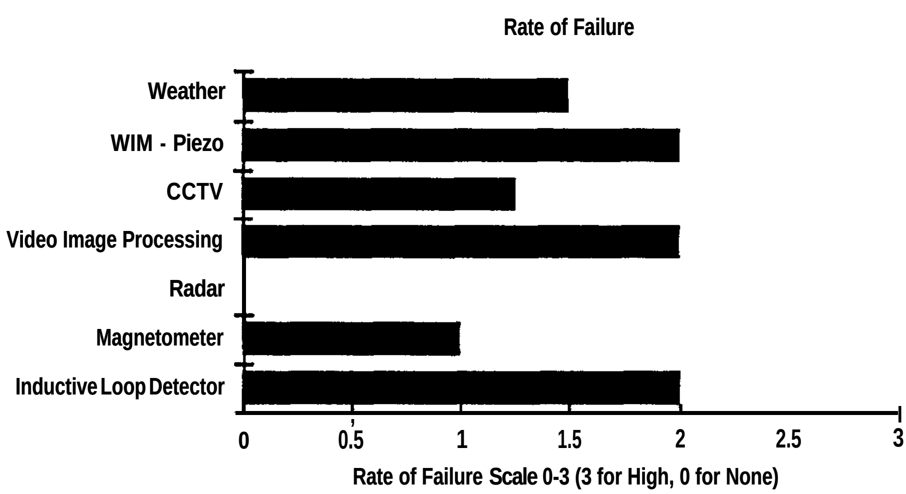

Figure 3-9. Rate of Failure of Sensors

Figure 3-10 illustrates the performance ratings of the sensors in terms of ease of installation, maintenance, and relocation. Almost all of the sensors are very difficult to relocate, except radar and video image processing. Overall, the radar sensor shows the best performance in this category.

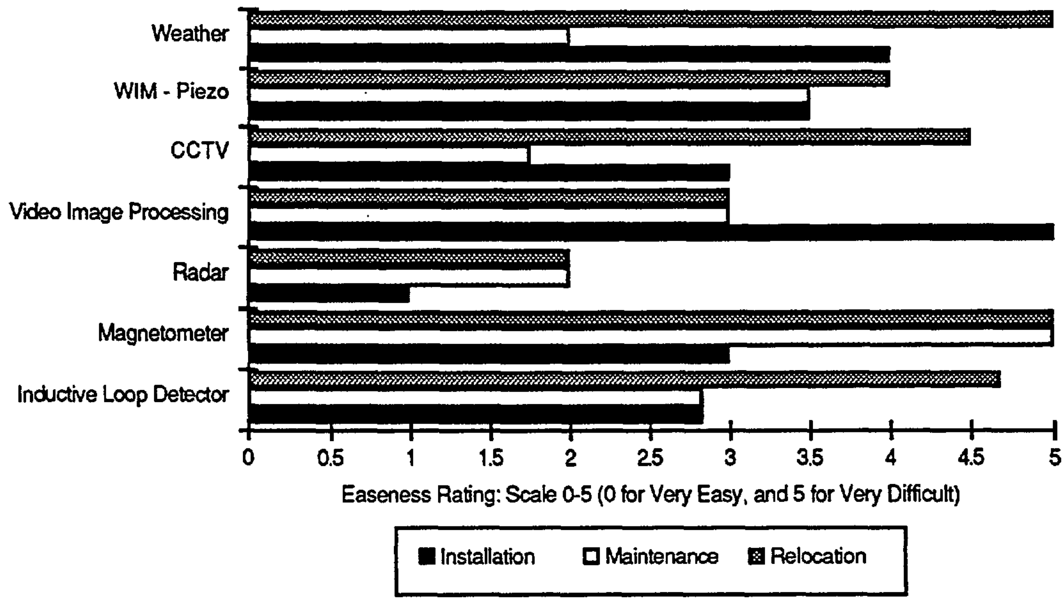

Figure 3-10. Ease of Sensor Installation, Maintenance, and Relocation

3.3.2.5 Use of Human Surveillance

A total of 19 respondents representing 16 agencies provided inputs on the use and effectiveness of human surveillance. Three categories of human surveillance were identified in the survey questionnaire: (1) police patrol; (2) freeway service patrol; and (3) motorist call-in. The survey responses indicated three additional means of human surveillance: (1) Good Samaritan Patrol; (2) call boxes; and (3) toll operators. Human surveillance seemed to be a significant commonality among the agencies. As shown in Figure 3-11, 81 percent of the agencies surveyed use police patrol and motorist call-in, and 69 percent use freeway service patrol.

<u>Effectiveness of Human Surveillance</u>

The percentages of effectiveness rating for each human surveillance method were calculated for each High, Medium, and Low subjective response (see Figure 3-12). The sample size for the effectiveness rating were 14, 10, and 12 for Police Patrol, Freeway Surveillance Patrol, and Motorist Call-In, respectively. The results indicated that police patrol seemed to be the most effective method.

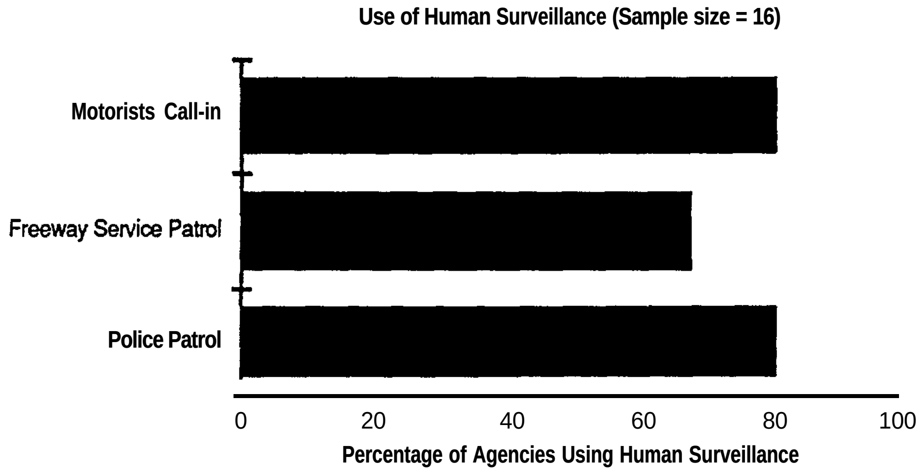

Figure 3- 11. Use of Human Surveillance by the Surveyed Agencies

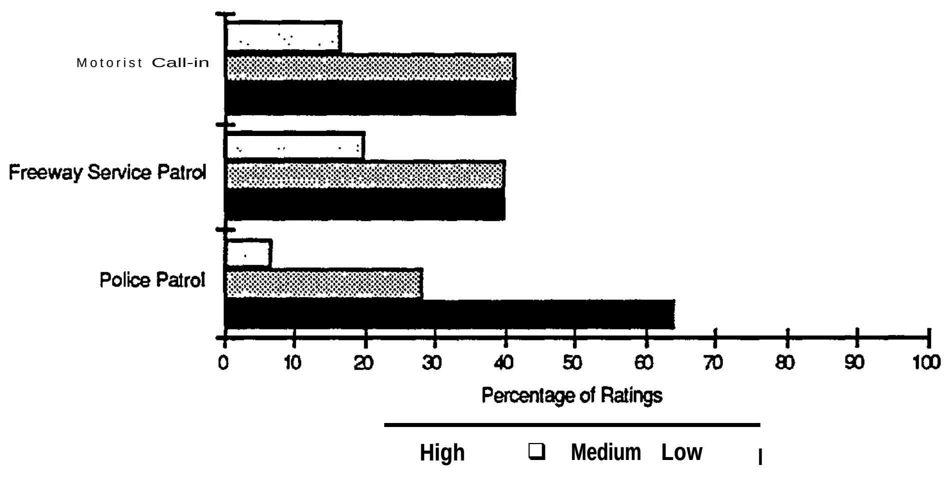

Figure 3- 12. Effectiveness Rating of Various Human Surveillance Types

Information Obtained from Human Surveillance

An overwhelming majority of the agencies use human surveillance for collecting traffic incident, accident, and disabled-vehicle information. Out of the total of 16 responding agencies, 13 agencies use police patrol , 10 agencies use freeway service patrol, and 11 agencies use motorist call-in to receive this information. A few agencies also reported to use human surveillance for weather, environmental information, traffic monitoring, and pavement condition information.

3.3.2.6 Transit Surveillance Capability

A total of five agencies responded to the questions related to the use of sensors. Three agencies reported to use Automated Vehicle Location (AVL) system for buses, and two agencies reported to use AVL for railway. One agency mentioned that the state police use AVL technology. Considering the limited number of transit agencies participating in the survey, the result indicated significant usage of AVL for transit vehicle management purposes.

3.3.2.7 Relevant Results from Traveler Information Services (Project #8) Survey: Current Involvement with Private Sector

Most jurisdictions currently operating traffic management systems in major metropolitan areas utilize a partnership of some form to supplement their surveillance capabilities. Prominent companies like Metro Traffic, Shadow Broadcast, and Traffax Traffic Network are the most popular. In fact, one or more of these three are used in most major cities throughout the Corridor. Reference is made to Table 3-14 for a summary of commercial traffic reporting firms by state.

Table 3-14. Commercial Traffic Firms and Locations in Corridor

State	City	Traffic Network Name
Connecticut	Hartford	Traffic Net
	New Haven	Traffic Net
	Fairfield County	Traffic Net
D.C.	Washington	Metro Traffic Control
	Washington	Shadow Broadcast Services
Maryland	Baltimore	Metro Traffic Control
	Baltimore	Shadow Broadcast Services
Massachusetts	Boston	Metro Traffic Control
	Boston	Smart Route Systems
	Springfield	Traffic Net
New York	Long Island	Metro Traffic Control
	New York City	Metro Traffic Control
	New York City	Shadow Broadcast Services
New Jersey	Rutherford	Shadow Traffic Networks
Pennsylvania	Philadelphia	Metro Traffic Control
	Philadelphia	Shadow Broadcast Services
Rhode Island	Providence	Traffic Net
Virginia	Norfolk	Metro Traffic Control
	Richmond	**Metro Traffic Control**

Table 3-15 describes a sample of the types of surveillance systems used today by commercial traffic reporting firms. The aerial support in particular is significant since, for most jurisdictions, the cost to operate and maintain an aircraft precludes its use.[1] Since companies like Metro Traffic operate their own aircraft and probe vehicles on a regular basis, their inputs can be valuable to a publicly operated traffic management system.

Table 3- 15. Surveillance Systems Used by Commercial Traffic Firms

Commercial Traffic Firm	Types of Surveillance Used
Metro Traffic Control	Aerial with 2-way radio/voice capabilities as well video from a camera mounted under the aircraft
	Probe vehicles (citizens) with cellular phones
	Limos and taxis services with radios or cellular
	In some locations electronic and/or human interfaces to public systems/agencies
Shadow Broadcasting Services	CCTV (view this as very important)
	Aerial with 2-way radio/voice capabilities
	In some locations electronic and/or human interfaces to public systems/agencies
	Probe vehicles (citizens) with cellular phones
Traffax Traffic Networks	99.9% scanners
	Limited CCTV
	Some probe vehicles (citizens) with cellular phones
SmartRoute Systems (SmartTraveler)	50 CCTV with live, slow scan and snapshot video
	Aerial with 2-way radio/voice capabilities
	Probe vehicles - 100 citizens with cellular phones; 100 with 2-way radio/voice capabilities; Buses with P-way radio/voice
	Tielines with Massachusetts Highway, commuter rails and state police
	Currentlv evaluatina overhead ultrasonic detectors

From a dissemination point of view, these companies are equally valuable in that they can disseminate traffic and weather-related data to a broad range of users. This is mostly accomplished through reports either directly or indirectly provided to radio and TV stations on a regular basis. Reports in most cities are updated and disseminated at 10-minute intervals. Lastly, in some cases these companies operate their own traffic radio networks.

In some locations, private companies like SmartRoute Systems in Boston, exclusively provide their own land-based and aerial surveillance equipment to acquire, analyze, and report traffic and

1 There are a few transportation agencies, however, that operate aircraft. Fairfax County Police currently operates a helicopter and Montgomery County, Maryland operates a Cessna 172 during peak hours.

weather conditions. SmartRoute Systems collects real-time traffic information by using CCTV cameras, aircraft, and probe vehicles. Their field personnel periodically call in to report traffic conditions. These companies play a similar role to commercial traffic reporting firms such as Metro, but are different in that they replace public agencies for operations of the traffic management center, and they also have their influential political support.

Many other companies such as Bell Atlantic, NYNEX, Cellular One, and AT&T supplement the incident reporting process by providing the communication infrastructure to allow cellular car phone users to, among other things, report incidents (e.g., 911). In addition, communication companies in many states are partnering with state DOTs and Authorities to install communication networks. Public agencies share the right-of-way in exchange for the use of new fiber networks.

Although there are quite a few partnerships in existence today, more integrated approaches need to be identified. There is a myriad of potential private sector partnerships that conceivably exist. The key challenge that must be overcome is new and improved mechanisms for public-private cooperation, coordination and communication, while not threatening the business interests of any involved party.

3.4 SITE VISITS

Site visits were conducted to supplement existing systems inventory information. The following criteria were used to select sites:

+ Sites for which data are not available otherwise.
+ Types of surveillance systems and technologies.
+ Size of system.
+ Sites that play critical role in the region.

Table 3-16 shows the candidate sites based on these criteria.

Table 3-16. List of Sites for Visits

Sites	Sensors to be Examined
Northern Virginia - Virginia DOT	CCTV Loop detection/ Incident algorithms Aerial surveillance (Helicopters)
Montgomery County, Maryland	Aerial surveillance (Fixed-wing aircraft) CCTV
TRANSCOM, New York/New Jersey	Vehicle probe/electronic toll collection
Washington. D.C.	Cellular telephone probes

Site visits to TRANSCOM, the Northern Virginia DOT, and the Montgomery County Maryland TMC were made. Since the Washington, D.C. cellular telephone probe operational test was delayed beyond the time frame of this task, it was visited. Details of the observation during these site visits are contained in the following subsections.

3.4.1 TRANSCOM

Operations Overview

From the tour of the facility it became apparent that TRANSCOM is one of the most unique traffic management systems in the U.S. Factors contributing to its uniqueness include the following:

+ It demonstrates that a variety of public agencies representing different jurisdictions can work in a cooperative manner and provide substantial benefit to the traveling public. The member agencies include:

N.Y. DOT	New Jersey DOT
N.J. Highway Authority	N.Y. State Thruway Authority
N.Y. City DOT	N.Y. & N.J. Port Authority
N.J. Turnpike Authority	N.J. Transit
N.Y. State Police	N.J. State Police
Palisades Interstate Park Commission	Triborough Bridge and Tunnel Authority
Metropolitan Transportation Authority	Port Authority Trans-Hudson

+ It demonstrates that substantial benefit can be achieved with the use of relatively simple technology

The primary purpose of TRANSCOM is to serve as a clearinghouse for travel information. Essentially, TRANSCOM receives travel information, such as construction activities and incident data, and ensures that those agencies requiring the data receive it. Interestingly, TRANSCOM does not have any surveillance capability of its own; it relies solely upon information provided by the agency responsible for the operation of the asset.

The control center is staffed by four operators who receive traffic status data through a variety of communication media including telephone, 2-way radio, and facsimiles. The operators are also provided with monitors that display the Weather Channel and the approaches to the Holland and Lincoln Tunnels. When a change in the status of the traffic network is detected, the operator looks up the appropriate standard operating procedure (SOP) in a PC based database. These SOPs are agreed upon by all of the member agencies before they are used operationally. TRANSCOM personnel pointed out that before any SOP is used, it must have the unanimous agreement of each of the agencies. The output of the database is primarily a list of agencies and individuals that should be contacted. In addition to notifications to the member agencies, TRANSCOM also notifies other organizations such as Shadow Traffic and DOT’s from non member states such as Connecticut and Virginia.

Integration of TRANSCOM’s System for Managing Incidents and Traffic (TRANSMIT) was in progress during the visit. This system leverages the ETTM standard developed for the E-Z Pass automated toll collection into a system for using the transponder equipped vehicles as probes. When the final system is complete an 18-mile section of the N.Y. State Thruway will be used for evaluating the probe vehicle system. Farradyne Systems’ MIST 2.0 product is the platform for collecting the probe data and performing incident detection.

Adjacent to the control center is a small recording studio that is used for developing and transmitting HAR messages. The interface to the various HARs is through a dial-up modem. Although many of TRANSCOM’s tasks are complex and challenging, simple technologies have been employed to effectively assist in the execution of those tasks. For example, to correctly identify a link in an area that may have several names, TRANSCOM implements a simple map system that consists of the Rand-McNally Road Atlas on CD. This allows the operators to perform searches using keys supplied by the person reporting the incident. The operator can then manipulate the map (“zoom”) to locate the area in question.

Future Projects

Video Switching System, TRANSCOM is in the process of implementing a video switching system in which it will serve as the video distribution hub. All video data from the member agencies will be routed to TRANSCOM, who will then switch the video data to those agencies requiring it. In the final system, receivers of the video will be able to receive the output from any camera but will not be able to control it.

Omnibus Routing System, This is in the pre-study phase. The proposed purpose of this system is to promote intermodalism by relaying traffic information to the transit agencies to optimize their bus routes.

SATIN, This is a proposed traveler information system. There is the realization that many of TRANSCOM's member agencies have an interest in providing kiosks for the general public to plan their trips. TRANSCOM intends to conduct a study that in many ways mirrors the activities under the I-95 Corridor Coalition's TIS project (Project #8). Specifically, TRANSCOM is interested in developing an understanding of traveler information service needs of member agencies; the level of participation in the operation of the system; and methods for financing the system, collection of revenues, and distribution of profits.

Expansion of TRANSMIT, If the results of the TRANSMIT project are promising, TRANSCOM will develop a system architecture and design for expanding the system to cover the entire metropolitan region.

3.4.2 Northern Virginia TMC (Virginia DOT)

The VDOT Traffic Management System (TMS) is a computerized highway surveillance and control system that monitors 30 interstate miles on I-395, I-495, and I-66 in northern Virginia. At the heart of the system is a TMC located in Arlington, Virginia. The TMC collects, monitors, and responds to information provided by the various sensors in the system. Hours of operation for the TMC are 5:00 AM - 12:00 midnight, seven days a week. TMC staffing includes two to three in-house operators to monitor traffic conditions and eight technicians to perform maintenance and repair functions on the interstate highways.

TMC Operational Activities

+ Monitor information from 550 loop detectors for incident detection and management. The detectors collect volume, average speed, and occupancy data. Data are polled every 1/4 seconds and used to detect incident. The aggregated data is also displayed on MAP-INFO with color coding. The display used four colors based on prevailing average speeds (e.g., green for speed greater than or equal to 45 MPH, yellow for speed between 35 MPH and 45 MPH, magenta for speed between 25 MPH and 35 MPH, and red for speed less than or equal to 25 MPH).

+ Monitor information from 46 CCTV cameras for incident detection and verification. The cameras are placed approximately 1/2 mile apart. There is one camera to over both directions. The cameras have pan/tilt/zoom (PTZ) capabilities and can turn 360°. The camera images are displayed on two sets of 4x4 monitors (a total of 32 monitors). There is a large screen on which any of the CCTV images can be displayed.

+ Monitor aerial surveillance information from one camera for incident detection and management. It is performed during AM and PM rush hours only.

+ Monitor call-in information for incident detection and management.

+ Monitor two units of Autoscope system, which provide incident detection information. The system also provides volume and speed data. These units were being tested for incident detection. Results to date were not satisfactory.

+ Monitor information from two carbon monoxide sensors and control exhaust fans for the I-66 Rosslyn Tunnel.

+ Monitor lumination sensor information and control visibility lights for the I-66 Rosslyn Tunnel.

+ Control 106 variable message signs providing motorist information.

+ Control 26 ramp meters regulating traffic flow onto the intestate highways.

+ Control eight sets of HOV lane access gates.

+ Inform Metro traffic, Shadow traffic, and State Police of incidents. They are also informed after the incident is cleared.

Current TMS/TMC problems

+ Damage to loop detectors by road paving crews.

+ Damage to underground cables by construction crews.

+ Ice build-up on CCTV camera screen.

+ Damage to HOV lane gates by motorists.

+ Character-based information displays are obsolete.

+ Inefficient arrangement of displays and buttons on Control Console.

+ Control Console user interface is outdated.

Future TMS/TMC Enhancements

+ Currently building a new Traffic Management Center building.

+ Expand surveillance from 30 miles to 66 miles of coverage.

+ Increase the number of loop detectors from 550 to 1150.

+ Increase the number of CCTV cameras from 48 to 125 (four cameras to be rapid scan).

+ Increase the number of VMS from 106 to 206.

+ Improve the video imaging techniques and aerial surveillance.

3.4.3 Montgomery County {Maryland) TMC

Montgomery County, part of the Washington, D.C. metropolitan area, has over 2000 miles of roads. The Montgomery County's Transportation Management Center (TMC) is used for both traffic and transit management. Thus, the acronym "TMC" should be interpreted differently in this case, rather than its usual use to describe only a traffic management center. The TMC's workstations and software are used by both transit and traffic engineering, operations, and planning departments to support a totally integrated transportation system.

With respect to traffic management, although the Montgomery County's TMC is primarily responsible for managing street traffic, traffic monitoring along I-270 using CCTV is also performed by the TMC's personnel. The facility displays most of the latest ideas in state-of-the-art ATMS/ATIS technology and traffic engineering products. The following is a summary of the TMC's technical characteristics:

<u>Surveillance</u>

+ Sixteen existing CCTV cameras. A total of 50 cameras will be available by 1995. There are also plans to expand the system to as many as 200 cameras. With a large number of cameras, the goal of the County is to minimize the monitoring task of operators by automating some elements of the system with machine vision technologies (using separate, fixed cameras) while maintaining other dedicated cameras for manual control.

+ Three thousand (3000) loop detectors. These also include control detectors for phasing and queue detection at intersections.

+ Aerial coverage from a county owned and operated Cessna 172 aircraft with "live" video and audio transmitted via wireless microwave communications directly to the TMC.

+ Automated incident detection system using loop data. Cameras, where applicable, are also used for incident detection and verification. The TMC has police radio now; later police computer-aided dispatch will be in the TMC on a separate workstation to support incident detection and management.

+ Testing of Autoscope units now and other machine vision systems in the future.

+ Receiving site for the Washington, D.C. Cellular Telephone Tracking Operational Project which provides probe data (e.g., link speeds, travel times).

+ Plans for a volunteer citizen probe report program called "Traffic WATCH." It will use a limited number of trained citizens to report incidents and traffic conditions.

Control

+ Six hundred fifty (650) traffic signals located on county and city surface streets. The system has a capability to grow to 1500 signals.

+ No VMS currently available. In the future, a few small VMS units for the city will be controlled by the TMC.

+ Comtrac control algorithm (Eagle Signal) running new or old NEMA and 170 controllers. It is capable of running in traffic-responsive or time-of-day mode.

Communications

- Four hundred (400) miles of twisted pair cable being replaced with fiber optic cable to support voice, data, and video exchange.

- Forty eight (48) count single-mode fiber optic backbone with 24 count feeders. It will support the County's plans to go with SONET and asynchronous transfer mode standards in the future. SONET support will be available in 1995.

+ Plans to expand the fiber network to the entire county in order to link other public agencies together (e.g., schools, police, fire, rescue, etc.).

+ Video links of about 8 megabyte bandwidth using COMLUX technology.

Control and Information System Characteristics

+ Data General minicomputers for data acquisition.

+ Sun SPARCstation 10 running Solaris 1, with 4 Gigabyte external storage. The County plans to acquire a SPARCstation 20 and/or Server 1000.

+ Informix relational database for storing 1, 5, 10, and 15-minute count data. Each detectors' one-minute count data is loaded into the DBMS every 1 minute. This can be customized to 2 minutes, 5 minutes, etc. Several months of historical data is obtainable from the DBMS.

+ Design emphasizing an open architecture.

+ Fairchild's Multimap GIS product allowing pan/zoom of a raster-scanned ADC map for Montgomery County. This product could use other GIS data (e.g., TIGER, Etak, etc.) but ADC is the current County standard. Various raster layers are used to display lower level map details (e.g., aerial photos digitized (digital ortho) and displayed in TIFF format. The TMC's GIS product can also access the county's GIS, which is ARC/INFO. The County plans to use a vector-based map to replace the current ADC map.

+ Motif GUI with red, yellow, or green dots to indicate traffic levels of service. Color coded links were being planned for implementation.

+ Logical reconfigurable links. These are defined as links between physical detection stations.

+ No Al or Simulation capabilities to date. The county plans to use Al for Incident Management.

+ Access to digital tape archives containing several years of historic traffic data.

<u>ATIS Features</u>

+ Traveler Advisory Radio (TAR) 590 AM and 1070 AM (between Route 29 and l-95).

+ Travel information dissemination through television. The County has a dedicated cable TV channel ("Traffic Channel" 55) displaying traffic video imagery, text, and audio TAR messages. In addition, News Channel 8, WUSA Channel 9, and WRC Channel 4 have direct access to live video imagery collected by the County's TMC. In the future, a color-coded link map (the same that used in the TMC) will be displayed on cable channel 55 along with the current live video imagery. Other counties have already expressed interest in receiving Montgomery county's traffic video data.

+ Traffic reports to 97.1 FM and other radio stations.

+ Plans to provide a dedicated server for information access (e.g., Mosaic, Modem, etc.) in order to not interfere with real-time control system in the TMC.

Transit Capabilities

+ Two hundred fifty (250) buses in the Ride-On fleet. About 70 to 80 buses are being installed with GPS-based vehicle tracking system for schedule adherence. Although transit vehicles will not be used as probes in the near future, information on buses that are behind schedule will be used to indicate the existence of traffic congestion along their routes.

+ Plans to provide information to transit travelers to increase ridership on county Ride-On buses.

+ Support for signal priorities for transit vehicles and preemption for emergency response vehicles.

Operations

+ Operates 24 hours a day.

+ Located at 101 Monroe Street in downtown Rockville; proposed future location is at Montgomery County airport.

+ Manned with two operators during peak-hour shifts. The County tries to automate its system as much as possible and use fewer, but higher skilled operators to support its TMC operations

+ Existing coordination with Metro and Shadow traffic control.

+ Member of Maryland's Chesapeake Advisories Routing Traffic (CHART) program. CHART is intended to become a state-wide traffic management system that will demonstrate coordinated traffic management facilities.

+ Member of Washington Capital Area Operations Management Team which includes VDOT, Montgomery County, DC, MSHA, police, fire, and rescue . This organization is designed to support regional traffic management activities.

Aside from the advanced features on display, the Montgomery County TMC is also unique in that it is the only county-run TMC (besides Baltimore County) that controls city signals. In addition, the system is the result of over 14 years of improvements and lessons learned in traffic engineering. An interesting note is that the system was designed by the County itself and a contractor was later selected to implement the solution.

3.5 SYSTEM INVENTORY: LITERATURE REVIEW

One guideline for this study is to use existing studies to the fullest extent possible. A literature search was conducted, but only a few documents relevant to the Corridor were found. This section provides the pertinent information extracted from the available documents.

3.51 Regional Traffic Information Center (RTIC) Study

The New Jersey Regional Traffic Information Center (RTIC) study contains information on the surveillance capabilities of the member agencies. Table 3-17 summarizes the RTIC member agencies' sensor systems.

3.5.2 State ITS Plans and Related Documents

Various state ITS plans and reports of ITS early deployment studies were reviewed. The following relevant information was found.

<u>Maryland</u>

Statewide Traveler Advisory Radio (TAR) currently using monopole technology will be enhanced. A few of projects will be completed in the near future, including 12 new VMS and 21 CCTV with complete digital transmission, 114 overhead detectors, and the Cellular Phone Operational Test.

Table 3- 17. RTIC Sensor Systems

RTIC Members	Sensor System
TRANSCOM	Does not have sensor system of its own. Monitors equipment (CCTV) owned by the member agencies. Receives incoming traffic and transit incidents information. Sponsoring development of an incident detection and traffic management system that uses AVI technology. It involves AVI readers at 1.5 miles spacing on roadways at the northernmost 8 miles of the Garden State Parkway and the New York State Thruway from the Spring Valley toll plaza to the Tappan Zee Bridge toll plaza.
New Jersey Turnpike Authority	At the northern end (ATSCS) between interchange 8A to Route 46 of NJ Turnpike, 940 loop detectors (for occupancy) are placed at 1.5 mile intervals. Data Collection centers are installed at each interchange. ATSCS also contain 2 CCTV cameras. Experimenting with video detection and acoustic/radar detectors. Expects to continue to rely on loop detectors. Plans to install 30 miles of fiber optic trunk service at ATSCS. and deploy major CCTV facilities.
New Jersey Highway Authority	Operates Garden State Parkway. Loop detectors are installed in the section north of NJ Turnpike interchange which is not yet connected to any central communication system. Plans to install 26 CCTV cameras along the northern section to cover all major interchanges. Plans installation of loop detectors at I/2 mile spacing, speed traps at 2 miles spacing and near major interchanges and plazas.
New Jersey DOT	Planned project MAGIC-1 will implement 31 CCTV cameras, 2 single loops, 2 speed traps, 146 radar detectors on I-80 corridor and I-95 approach to the George Washington Bridge.
Port Authority of New York and New Jersey	Existing systems include cameras on GW bridge, ETTM, AVI, video detectors and loop detectors. Has 13 CCTV Cameras on the GW bridge. Plans to install 23 cameras on the New York side of the GW bridge. Will implement ETC as a member of E-ZPass Consortium.
New Jersey Transit	Testing AVL system in the northern part of New Jersey for locating each bus on route and displaying graphically. This system will also provide link travel times. Has 48 camera CCTV surveillance system for the Newark subway.
New Jersey State Police	Likes to have access to CCTV control cameras and weather station information.

Upon the completion of building the new Statewide Operations Center (SOC), the State will have an enhanced capability to handle VMS, TAR, traffic signals, vehicle detection, and video surveillance with a user-friendly interface.

Pennsylvania

A Traffic and Incident Management System (TIMS) has built in Philadelphia. It currently has 310 loop and overhead detectors combined and 196 CCTV cameras.

3.6 SURVEILLANCE GAPS

This section discusses gaps in surveillance coverage throughout the corridor as identified through the survey. A surveillance gap is a geographic area where there is no capability for detecting, collecting, and disseminating vehicle detection or environmental data while the data were needed. In analyzing the surveillance coverage of the corridor we identified surveillance coverage in terms of functionality: that is the type of data that an individual sensor is capable of providing. Sensors can be divided into the following three functional groups:

+ Direct Traffic Network Status Sensors. These are sensors whose primary purpose is surveillance of the traffic network. Typical sensors of this class measure vehicle presence at one particular geographical location. This class of sensors typically provides vehicle detection, occupancy, and speed data. Included in this class are loop detectors, magnetometers, RADAR, and video image processing (e.g., AutoScope).

+ Indirect Traffic Network Status Sensors. These are sensors whose primary purpose is to provide a functionality other than traffic network surveillance. Examples of these types of sensors include:

  - CCTV. Its primary function is to support incident detection and management and requires human intervention to achieve this function.

  - WIM. The primary function of these sensors is to support commercial vehicle operations: traffic network status is a by-product of this functionality.

  - AVI/AVL. The primary function of these sensors is to support ETTM; the use of this technology as probes is secondary.

+ Environmental Sensors. These sensors provide information about weather and roadway conditions.

General Observations

Reference is made to Subsection 3.323 which provides the specific surveillance gaps identified by the surveyed Coalition members. In this subsection, an attempt is made to identify a general lack of surveillance within the Corridor by examining the existing surveillance infrastructure and the needs of the region.

Figure 3-1 in Section 3.3 provides the AutoCAD drawing of the I-95 Corridor with existing and planned sensor information that was received from the survey. It should be noted here that the survey response rate is 81 percent. As such, the drawing misses the data not received from the rest (19 percent) of the agencies. Also, the survey responses appeared to under-report many types of existing surveillance systems in the Corridor. Therefore, assessment of the surveillance gaps should be conducted very carefully.

Existing surveillance coverage in the corridor is sparse and inconsistent. The analysis of the data gathered in the survey indicates that the majority of surveillance capabilities are centered on the Corridor's major urban areas. With the exception of Pennsylvania and the New Jersey Turnpike, no state has a complete complement of traffic network sensors. However, most states have limited implementations of spot detectors. It is also apparent from the survey data that the focus of existing sensor deployments has been upon direct traffic network sensors. In terms of the indirect sensors, most states have limited deployments of CCTV in the major urban areas. Virginia has deployed SCAN sensors all along I-95, no other state has a more extensive environmental surveillance network. It is also apparent that I-95 is the focus of the Corridor; there is virtually no existing surveillance capability on the crossing interstates or major arterials. Future plans for the deployment of surveillance capabilities center on the implementation of loop detector and CCTV systems. There are limited deployments (primarily proof of concept tests) of other forms of surveillance throughout the Corridor.

Gaps Identified Based on Needs

The surveillance gap in this context is needs-based, e.g., a gap exists within a segment of roadway if a certain surveillance is absent even if it is warranted at that location. Specific gaps were identified based on the specific needs of the I-95 Corridor.

Since incident detection and management has been found to be the number one goal of the Coalition, the adequacy of sensors for this purpose is the prime consideration. Sensors are needed for incident detection and follow-on verification and management. The surveillance needs for the detection and management of an incident include an automated incident detection system (generated by processing real-time volume-speed-occupancy data) and a means for monitoring such as CCTV. Since congestion is a problem with major metropolitan areas rather than rural roadways, incident management is critical. Major metropolitan areas in this Corridor include Richmond, Washington-Baltimore, Philadelphia, New York, Boston, and Hartford. A careful examination of Figure 3-1 indicates that while the Washington area has some coverage of loop detectors and CCTV monitors, the Baltimore area has a surveillance gap from an incident management standpoint. However, the drawing also indicates that vehicle detection systems and CCTV are planned for this area. Similarly, Philadelphia and New York seem to lack incident management surveillance capability. Since no data was received to date from Massachusetts, an assessment of Boston could not be made. The drawing indicates some surveillance capability in the Hartford metropolitan area.

Another aspect of Corridor's needs is real-time traffic management, for both freeway and surface streets, which need real-time surveillance information virtually similar to the requirements for incident detection. Therefore, similar conclusions, as in the above paragraph, are made on surveillance gaps related to real-time traffic management.

The results of the goals survey (Chapter 2) indicate that weather sensors are a high priority technology area for the Coalition Members. Weather monitoring is very important for this Corridor, considering the entire area deals with traffic management under ice, snow, and fog. Thus, the weather surveillance needs exist throughout the Corridor, including both rural and urban areas. Figure 3-1 indicates that the entire Corridor severely lacks the weather and environmental sensors necessary for detection of ice and fog. The stretch of I-95 in the Virginia and Washington-Baltimore areas has some coverage of environmental sensors, while the rest of the Corridor lacks these types of sensors.

Finally, considering the advances of future technology, various ITS implementations will require more sensor data. The need for surveillance data will increase dramatically from existing volume-speed-occupancy data to travel time, dynamic O-D data, real-time delay and queue-length information. Advanced sensors such as AVI/AVL will be of prime importance in the future. From this perspective, the entire Corridor lacks the necessary surveillance. However, the current unavailability and premature state of technology is the reason for this gap.

3.7 COST EFFECTIVENESS COMPARISON BASED ON SURVEY DATA

As described in Section 3.3, a limited number of responses to cost related questions were received. From the survey, an initial data set of cost and performance information for seven sensor categories was collected. There were some limitations in using this data for a full-blown analysis. First, the cost and performance data were not reported for all the sensor alternatives. Second, the sample size for the responses were small. Third, the cost data varied greatly. Yet, a limited-scale comparison using the survey data was deemed reasonable and provided valuable insight into the sensors' relative performances, based on the hands-on experience of the Coalition members. A more detailed analysis of surveillance technologies is presented in Chapter 4 (Technology Assessment).

3.7.1 Survey Results

The elements of the survey related to cost and performance of the seven sensor types is presented in Table 3-18. From the survey data the following general headings were collected:

- Initial Cost. This data point reflects the unit cost of the individual sensors.
- Operations and Maintenance Cost. Reflects expenses incurred on a recurring basis.
- Satisfaction on Data Accuracy. A subjective rating (ranging from 0 as *unsatisfactory* to 3 as *highly satisfied)* that reflects the respondents perception of the accuracy of the data received from the sensor.
- Fulfillment of Purpose. Also a subjective rating, using the above scale, that reflects the sensor capability to perform as the respondent expected.
- Rate of Failure. A subjective rating (ranging from 0 as *never fails* to *3* as *high failure rate)* that measures the respondent's experience with the reliability of the sensors.
- Ease of Installation. A subjective rating (ranging from 0 as very *easy* to 5 as very *difficult)* that measures the respondent's experience with installation of the sensor.

+ Ease of Maintenance. This category measured the relative maintenance experience that the community has with the sensor. The 0-to-5 scale above was used for this category.

+ Ease of Relocation. With the 0-to-5 scale, this data element measures the relative ease of reconfiguring the sensor network.

Table 3-19. Sensor Cost Performance Data from the Survey

Sensor Type	Initial Cost	O&M Cost	Data Accu.[a]	Ful. of Purpose[a]	Rate of Failure[b]	Ease of Install.[c]	Ease of Maint.[c]	Ease of Reloc.[c]
Inductive Loop Detector	$1,100	$130	2.3	2.67	2.0	2.8	2.8	4.7
Magnetometer	N/A	N/A	1.0	3.0	1.0	3.0	5.0	5.0
Radar	$25,900	N/A	2.0	2.0	0	1.0	2.0	2.0
Video Image Processing	N/A	N/A	2.0	3.0	2.0	5.0	3.0	3.0
CCTV	$14,400	$3,700	2.0	2.53	1.3	3.0	1.8	4.5
WIM - Piezo-electric	$3,100	$1,000	2.5	3.0	2.0	3.5	3.5	4.0
Weather - SCAN	$50,600	$2,000	2.5	2.5	1.5	4.0	2.0	5.0

a On a 0-3 scale (0 for Unsatisfied, and 3 for Highly Satisfied)
b On a 0-3 scale (0 for Never Failed, and 3 for High Failure Rate)
c On a 0-5 scale (0 for Very Easy, and 5 for Very Difficult)

As can be seen, much of the data used in this analysis is subjective in nature. This approach was selected for several different reasons. The primary reason is that there are no consistent methods to collect and report cost and performance data. Each agency has its own metrics for maintaining this data. It was felt that any attempt to 'normalize" cost data across the agencies would be inconsistent with the projects schedule. Another factor that contributed to this decision is that a more thorough analysis of sensor technologies was performed in the Technology Assessment (Chapter 4).

Of the seven classes of sensors presented in Table 3-18, there is an overlap in functions between inductive loop detectors, magnetometers, radar, and video image processing. These four sensors all share similar traits in that they provide vehicle detection, occupancy, and speed data. While several of these detectors are capable of providing additional pieces of data, this analysis maintains a focus on the three data elements above to provide a common framework for comparison. CCTV, WIM, and SCAN provide other types of information. The Corridor's collective experience with these technologies is reported here.

A comparison of effectiveness of the first four sensors indicates that inductive loops provide satisfactory performance for almost all categories except relocation. It provides higher accuracy of data than the other three. Radar sensors have a lower rating of data accuracy and fulfillment of purpose than inductive loops. Yet, its rating on the ease of installation, maintenance, and relocation are superior to those of the other three candidate sensors. On the other hand, the magnetometer provides a low data accuracy, but provides a high satisfaction with fulfillment of purpose (this contradiction can be attributed to very low sample size). Magnetometers are found to be very difficult to maintain and relocate. Video image processing Is comparable to inductive loops in terms of data accuracy and fulfillment of purpose. Although, it is very difficult to install, it has its strength in ease of relocation, which is relatively easier than loop and magnetometer (however, radar still indicates an easier relocation). The comparison indicates an overall equal level of performance for both inductive loops and video image processing and the trade-off is between installation and relocation. However, current video image processors emulate the loop detector data and also detect incidents. It is not known whether the reported satisfaction rating of video image processing relates to only loop detector emulated data or the other data (such as incident detection). In one of the site visits for this project, it was reported that video image processors failed in generating appropriate detection of incidents.

CCTV shows remarkable effectiveness. In terms of data accuracy (picture quality) and fulfillment of purpose, the experience with CCTV is relatively high. The only disadvantage is relocation. It is also relatively easier to maintain. Its sensitivity to environmental factors, such as ice and frost on the lens and weather and lighting conditions, was noted as a problem.

The piezo-electric WIM indicates a moderate performance, and it received a high rating for fulfilling the purpose.

The weather sensor SCAN provides moderately satisfactory performance with a low rate of failure and relatively easy maintenance.

In conclusion, from a performance standpoint, inductive loops and radar sensors seem to be competitive candidates. CCTV provides high effectiveness. Piezo-electric WIM and weather sensor SCAN also provide satisfactory effectiveness.

As described previously, cost comparisons are inappropriate based on the data obtained from the survey. Because many of the sensors are not widely deployed, cost data drawn from the survey's information is insufficient for a meaningful analysis. In addition, costs are dependent upon a design configuration. One can not simply compare the unit cost of two candidate sensors. In order to compare the costs associated with the sensors, estimates need to be made for the costs of installation of the sensors for implementing the same level of functionality within the same area of coverage. For example, comparison of aerial surveillance could be comparable to numerous CCTV camera installations. It again depends on the design configuration, such as placement of CCTV cameras, or whether there is one camera for one direction or both directions. In addition, a cost comparison using a certain design configuration may produce an unintentional bias, if the configuration is not used later during implementation.

3.7.2 Sensor Performance Comparison Summary

The results of the effectiveness comparison provided an insight into the operation of a number of sensors. The effectiveness data in the form of subjective rating was very important because it provides the hands-on experience of the Coalition members. A full-fledged cost comparison could not be performed due to the inadequacy of survey data. Still, the survey data generated performance information for a number of sensor types.

The effectiveness comparison indicates a close competition between inductive loops and radar sensors. The effectiveness of CCTV seemed very satisfactory; this is also evident from the agencies' overwhelming future plan for installing CCTV surveillance in the future. Piezo-electric WIM and SCAN also appeared to be satisfactory.

A more detailed cost-effectiveness analysis (under a limited set of assumptions) is presented in Chapter 4 (Technology Assessment).

3.8 SUITABILITY ANALYSIS

In the Goals and Objectives Survey, the respondents placed a high level of importance on enhancing traffic incident management, real-time traffic control operations, traffic management during snow storms and other emergencies, multimodal and intermodal operations, and Traveler Information Services (TIS), in that order. A lower level of importance was placed on enhancing transportation planning databases, facilitating Travel Demand Management (TDM) strategy implementation, and supporting traffic law and regulation enforcement. To support these goals, the surveillance system must provide data as shown in Table 3-l 9.

Table 3- 19. Surveillance Data Needed to Support Identified Goals

User Service	Typical Data Requirements	Typlcal Implementation
Traffic Incident Management	Time of occurrence and location of incident, and incident severity information: occupancy, speed and volume; travel times; origin-destination data; traffic signal data; and response vehicle locations	Automatic incident detection and coordinated response plans
Real-Time Traffic Control Operations	Occupancy, speed, and volume; travel times: origin-destination data: and traffic signal data	Ramp metering, real-time traffic adaptive signal control, and HOV operations and variable message control
Traffic Management During Poor Weather Conditions	Occupancy, speed, and volume: travel times; origin-destination data; traffic signal data; weather data: roadway conditions data; and response vehicle locations	Support adaptive control, and support snow removal scheduling and operations
Multimodal and Intermodal Transportation Operations	Link travel times for time of arrival estimates and passenger loading estimates	Track transit vehicle location and schedule adherence
Traveler Information Services	Traffic condition information, roadway condition information, and transit information	Traveler kiosks; route guidance; and interface to public media (i.e., radio and television)
Transportation Systems Planning Database	Traffic count data, incident data, and traffic composition data	Route planning; HOV planning; capital improvements; and safety issues
Travel Demand Management	Travel times, traffic conditions, and origin-destination data	Identify traffic congestion locations and levels, and characterize traffic demand levels
Support Traffic Law And Regulation Enforcement	Speed measurements, weight measurements, and vehicle height and weight measurements	Speed, overweight, and overheight enforcement

The ability of the existing system to meet these goals may be examined as follows.

3.8.1 Geographical Coverage of Existing Systems

This section discusses the general geographic coverage of the existing system and required system expansion.

Vehicle Detection

A review of the SR/T existing systems inventory has revealed that the existing vehicle detection coverage throughout each of the member agency's area is not sufficient to meet the goals and objectives of the I-95 Corridor Coalition and the national goals of ISTEA. Where vehicle detection systems are implemented, these systems are either placed in urban areas to monitor recurring and non-recurring traffic congestion or to collect tolls. Considering just the urban areas, a number of cities do not have adequate vehicle detection systems operating. To improve traffic management throughout the I-95 Corridor, vehicle detection systems must be implemented throughout the roadways leading into urban regions and beltways. To achieve this, a substantial increase in the number of vehicle detection systems deployed is required. Also, an increase in the level of surveillance coverage is necessary.

Under the ISTEA national goals, state transportation agencies are required to monitor roadway performance to determine the capacity, efficiency, and safety of the highway system. Typically, states use vehicle detectors throughout the roadways to gather vehicle speed, volume, and occupancy data to meet the objectives of ISTEA. State agencies can implement traffic counting facilities and vehicle detection systems at discrete locations throughout the roadway system to achieve this goal. At present, a number of the states have either implemented this data collection network or are planning to do so in the near future. However, it is necessary that all states do so. In addition, at present, a number of these systems are not monitored remotely (i.e., the data is retrieved manually from the detector stations). It would be preferable if automated data collection facilities were expanded (using dial-up lines for example) to include all of the vehicle detection sites.

Closed-Circuit Television

Typically, Closed-Circuit Television (CCTV) is used in conjunction with incident detection systems to verify traffic incident reports and to determine the level of response required. Survey data has revealed that the existing CCTV coverage is inadequate to meet the goals and objectives of the I-95 Corridor Coalition. The majority of member agencies do not have existing CCTV systems for traffic management. Such facilities should be provided to include, at a minimum, all of the major metropolitan regions in the Corridor.

Aerial Surveillance

Aerial surveillance is an emerging technology for use in wide-area surveillance coverage. The survey has shown that the use of aerial surveillance was very limited.

Weiaht Sensors

Weigh stations are normally placed at discrete locations along a roadway and at a state's boundaries for collecting traffic composition and classification data. Currently, the member agencies appear to have adequate coverage of weigh stations to meet the need. However, as discussed above, it is possible to automate these weigh stations using a combination of Weigh-in-Motion (WIM) and Automatic Vehicle Identification (AVI) technologies. With respect to monitoring vehicle weights and classifications for pavement monitoring purposes, the states do not appear to have adequate coverage. However, such monitoring is not a high-priority objective of the member agencies.

Automatic Vehicle Location

At present, Automatic Vehicle Location (AVL) is used only by transit agencies in the member states. However, AVL transmissions, such as Global Positioning System (GPS) information, are available in all the member agencies' jurisdictions. The expansion of the AVL systems to cover entire metropolitan areas, with an adequate user base, would provide a very reliable source of traffic condition data.

Environmental Sensors

The coverage of environmental sensors is, at present, very limited. They are most needed at two types of locations: rural areas, where they can be used to advise agencies of the need for sanding or graveling and to warn motorists; and bridges, where they could be used to warn motorists of icy conditions.

3.8.2 Degree to Which Technologies Address Criteria

Vehicle Detectors

Of the technologies currently used by the member agencies, all but the magnetometer are capable of providing the basic traffic data: speed, volume, occupancy, and queue length. The magnetometer only provides volume, and as a result, is suitable to applications requiring only this type of data (for example, for planning or highway performance monitoring purposes). Inductive loop technology is by far the most accurate of the technologies used; however, in-pavement mounting is required.

Based on the results of the surveys, it appears that the technologies currently deployed for vehicle detection would be suitable for integration into a Corridor-wide surveillance strategy. The vast majority of the detectors have remote communications capabilities; only a few of the loops are attached to counters which must be read manually in the field.

Closed-Circuit Television

The surveys report CCTV is used by a few of the member agencies. Typically, these agencies used leased telephone lines or fiber-optic cable for communication with the cameras. These systems are suitable for integration into a Corridor-wide approach to surveillance.

Weight Technologies

Of the two technologies reported in use for weighing vehicles, only the piezo-electric axle load is suitable for use as a WIM device. The deep-pit weigh scale is used in conjunction with a traditional roadside weigh station. The surveys reported very little use of either technology; however, it is likely that most of the states within the Coalition use some form of roadside weigh station. Although such weigh stations are still usable, the state-of-the-art is moving toward WIM sensors used in conjunction with AVI technologies. Such a procedure eliminates the need to delay commercial vehicles at weigh stations, thereby increasing productivity, and the coverage of the weigh station. The weigh station does not need to be manned to be operable. The Coalition should move toward WIM technologies. However, a remaining issue to be resolved is the selection of suitable WIM devices.

Automatic Vehicle Location

The surveys reported little use of this technology by the member agencies; however, there are plans to implement it in several additional areas. AVL systems, when tied to an integrated central system, provide very good details regarding the current state of the system. With a sufficiently large sample size, they can provide data regarding the travel times on all of the links in the system. One drawback of the current implementations of this technology is that they are only installed in transit vehicles. Travel times obtained using buses as probes are often inadequate, due to the fact that these vehicles stop frequently for reasons unrelated to traffic levels. However, these systems do provide some level of information on roadway conditions and could be incorporated into an enhanced system.

Environmental Sensors

The surveys reported little use of environmental sensors by member agencies. However, the existing sensors provided a full range of environmental data, including air temperature, pavement temperature, and pavement condition (wet, dry, etc.). These data could be used not only for the signing of dangerous driving conditions, but also for scheduling de-icing and sanding activities. The existing facilities appear suitable for integration into a Corridor-wide strategy.

3.8.3 Identification of Gaps in Functional Coverage

The existing technologies used are functionally deficient in a number of areas.

+ There are few capabilities in place for the collection of system delay levels and travel times (except for limited outfitting of buses as discussed earlier). Such data is required for a number of ITS user service objectives, such as identifying traffic congestion levels.

- The member agencies report no use of technologies for height/width detection. However, it is apparent from other sources that such technologies are in limited use at some specific locations, such as at tunnels.

- There are no measures in effect for the detection of disabled vehicles, except for a few incident detection systems only effective under medium to heavy traffic conditions.

- Suitable WIM technologies are not widely used at vehicle weighing facilities. Such technologies would permit the automation of vehicle weigh stations, enhancing the commercial vehicle inspection process.

- There has been some investigation and use of AVI technologies in the Corridor for electronic toll collection. However, although there has been some attempt achieve regional compatibility, there is currently no Corridor-wide standard for the transponder devices. AVI technologies are necessary for electronic toll collection, congestion pricing, and weigh station automation. In addition, they may be used for travel time estimation.

- The member agencies reported no use of integrated parking lot surveillance measures, which could otherwise enhance the effectiveness of TDM strategies and intermodal coordination.

3.8.4 Summary

In summary, the existing surveillance systems are not completely suitable for supporting the goals of the Corridor. However, to preserve investments, the existing systems certainly should be integrated with the future system to accommodate the required functionality of a Corridor-wide surveillance system. On a broader note, all of the agencies expressed some level of dissatisfaction with the cost, maintainability, and/or effectiveness of their existing systems. It is important to investigate surveillance technologies combining ease of use, effective surveillance, ease of maintenance, and the lowest cost possible.